NONLINEAR ANALYSIS OF BIOLOGICALLY REALISTIC WALKING PATTERN EMULATOR

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The hind leg movement of a cat has four basic phases. These are called Stance, Lift off, Swing and Touch down. Each movement needs the activation of different muscles of the leg depending on the particular bones that must be moved. In this research project the complete movement of each hind leg in a vertical plane is assumed to be obtained by proper activation of seven muscles. The time instant at which a particular muscle is activated is usually determined by a neural controller and also the rate of contraction of the muscle is governed by the level of activation. A set of triggering rules are used for changing from one phase to the next phase mentioned above. The decision on when to change phase is mainly taken by monitoring the joint angle associated with the joint about which the particular bone is moved. This decision as was mentioned earlier is also taken by the neural controller. Previous studies show that the different speeds in the movement can be achieved by changing the activation levels (magnitudes) to relevant muscles. In addition to the activation level, the muscle force is also dependant on the muscle length (i.e. amount of its deviation from the non-contracted position) and muscle velocity (rate of contraction). Based on these observations, researchers have built up different muscle models, where some form of a description of variation of muscle force with the above three parameters are described. At the preliminary stage of this project, it is reasonable to assume that the muscle force is a function of muscle activation, muscle length and muscle velocity.

The overall project is aimed at proposing suitable design suggestions for a linear electromechanical actuator, which could successfully emulate dynamical properties of a muscle, when augmented with nonlinear behaviors of real muscles using control. In the first prototype, only one repeated movement of a single bone, for which usually two muscles are involved, will be demonstrated. When it comes to design and construction of a hind leg emulator, the local control problem can be described as the rotation of a rigid member (representing a bone) hinged at one end, by means of a force applied on it from (muscle force) a point at a distance from the hinge. The force that creates the rotation in the emulator is the force generated by the actuator replacing the muscle.

Being associated with several nonlinear properties, even the most preliminary modeling of this dynamical system leads to a complicated nonlinear system. This paper will present the modeling and preliminary analysis of the dynamical system comprising one bone under the actuation of a single muscle. The basic modeling leads to a nonlinear dynamical system with four state variables and muscle activation level being the external input. The state variables are the angle, angular acceleration of the bone, muscle length and muscle velocity. The final aim of this modeling and analysis is to design a linear actuator which can replace the muscle when augmented with a control system that will introduce the essential nonlinear properties to the system.

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