# Gait Optimisation using GA

Experimentation with gait generation using deterministic formulation as derived in previous papers reveals that the quadruped gait results into instability and toppling during the swing phase of the legs. Experimentation also reveals the inability of the quadruped to traverse in uneven terrain. To mitigate these problems and learn a more optimal gait, a Genetic Algorithm optimisation framework is proposed. To use this framework an appropriate problem and objective formulation is required. This paper describes the results of the preliminary literature survey and the inferences from the same.

Optimisation using Genetic Algorithm involves the following-

- A Genetic sequence formulated to represent the optimisation problem
- An Objective or fitness function to determine the selection criteria of genetic sequences from a population
- An initial population

## Initial Population

The gait formulation derived in previous work can be used to generate the initial gait population.

The following formulation is the previously derived gait formulae-

**Hip Activations:**

$$\theta_h(t) = \begin{cases} \theta_h sin(\frac{(t-\frac{iT}{4})\pi}{\beta T} + \pi), & \text{if } 0 \leq t \leq \frac{\beta T}{2} \\ \theta_h sin(\frac{(t-\frac{iT}{4})\pi}{(1-\beta)T} + \frac{(3-4\beta)\pi}{2(1-\beta)}), & \text{if } \frac{\beta T}{2} \leq t \leq \frac{T(2-\beta)}{2} \\ \theta_h sin(\frac{(t-\frac{iT}{4})\pi}{\beta T} + \frac{(\beta-1)\pi}{\beta}), & \text{if } \frac{T(2-\beta)}{2} \leq t \leq T \end{cases}$$

For $i \in \{0,1\}$

And

$$\theta_h(t) = \begin{cases} -\theta_h sin(\frac{(t-\frac{iT}{4})\pi}{\beta T} + \pi), & \text{if } 0 \leq t \leq \frac{\beta T}{2} \\ -\theta_h sin(\frac{(t-\frac{iT}{4})\pi}{(1-\beta)T} + \frac{(3-4\beta)\pi}{2(1-\beta)}), & \text{if } \frac{\beta T}{2} \leq t \leq \frac{T(2-\beta)}{2} \\ -\theta_h sin(\frac{(t-\frac{iT}{4})\pi}{\beta T} + \frac{(\beta-1)\pi}{\beta}), & \text{if } \frac{T(2-\beta)}{2} \leq t \leq T \end{cases}$$

For $i \in \{2,3\}$

**Knee Activations:**

$$\theta_k(t) = \begin{cases} \theta_k sin(\frac{t\pi}{T(1-\beta)} - \frac{\beta\pi}{2(1-\beta)}), & \text{if } \dot{\theta}_h(t) \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

For $i \in \{0,1\}$

And

$$\theta_k(t) = \begin{cases} \theta_k sin(\frac{t\pi}{T(1-\beta)} - \frac{\beta\pi}{2(1-\beta)}), & \text{if } \dot{\theta}_h(t) \leq 0 \\ 0, & \text{otherwise} \end{cases}$$

For $i \in \{2,3\}$

# Problem Formulation

Problem Formulation involves selecting a set of parameters that will determine the genetic sequence that will be optimised. From previous experimentation and literature survey, it is known that the gait of a quadruped depends on the following parameters-

- Swing Period
- Stance Period
- Hip Swing Angle (Maximum and Minimum)
- Knee Swing Angle (Maximum and Minimum)

One way to incorporate these factors into the genetic sequence would be use the encodings of these factors directly in the sequence. But this would still constraint us to the sinusoidal gait that was derived as a part of the original gait formulation.

To overcome this problem, **polynomial functions** can be used to approximate the gait patterns. The parameters of the polynomial functions can be used as the parameters in the genetic sequence. Moreover, the aforementioned four parameters can be inferred from the resulting polynomial. Although this increases the amount of computation involved in the optimisation process, it gives greater flexibility to the Genetic Algorithm to deviate from the originally derived gait formulation and reach a more optimal solution.

# Objective Formulation

To calculate the fitness function for selection, the following criteria are to be quantified-

- The Stability of the quadruped
- The Maximum Speed Achievable
- Joint Torque Requirements

## Stability of Quadruped

The Stability of the quadruped can be quantified by either formulating the position of the COM of the quadruped or the Zero Moment Point of the quadruped. The criteria of the COM remaining within the support polygon is the prerequisite for static stability and that of ZMP inside the support polygon is prerequisite for dynamic stability.

## Maximum Speed Achievable

We Already have a relationship between the maximum speed of the quadruped for a given set of motion parameters ($T_{st}$, $T_{sw}$ and $\theta_h$ ). This relation can be used for the quantification of this criteria.

The following formulation is the quantification of maximum speed wrt to the aforementioned parameters-

$$v = \frac{2L_T\theta_h}{T_{st} + T_{st}}$$

Here $L_T$ is the thigh length of the quadruped.

## Joint Torque Requirements

Further literature survey is required to find a quantification of the joint torque values and integration of this criteria  in the fitness function.