Fundamental Frequency Vs Speed analysis of Gait patterns

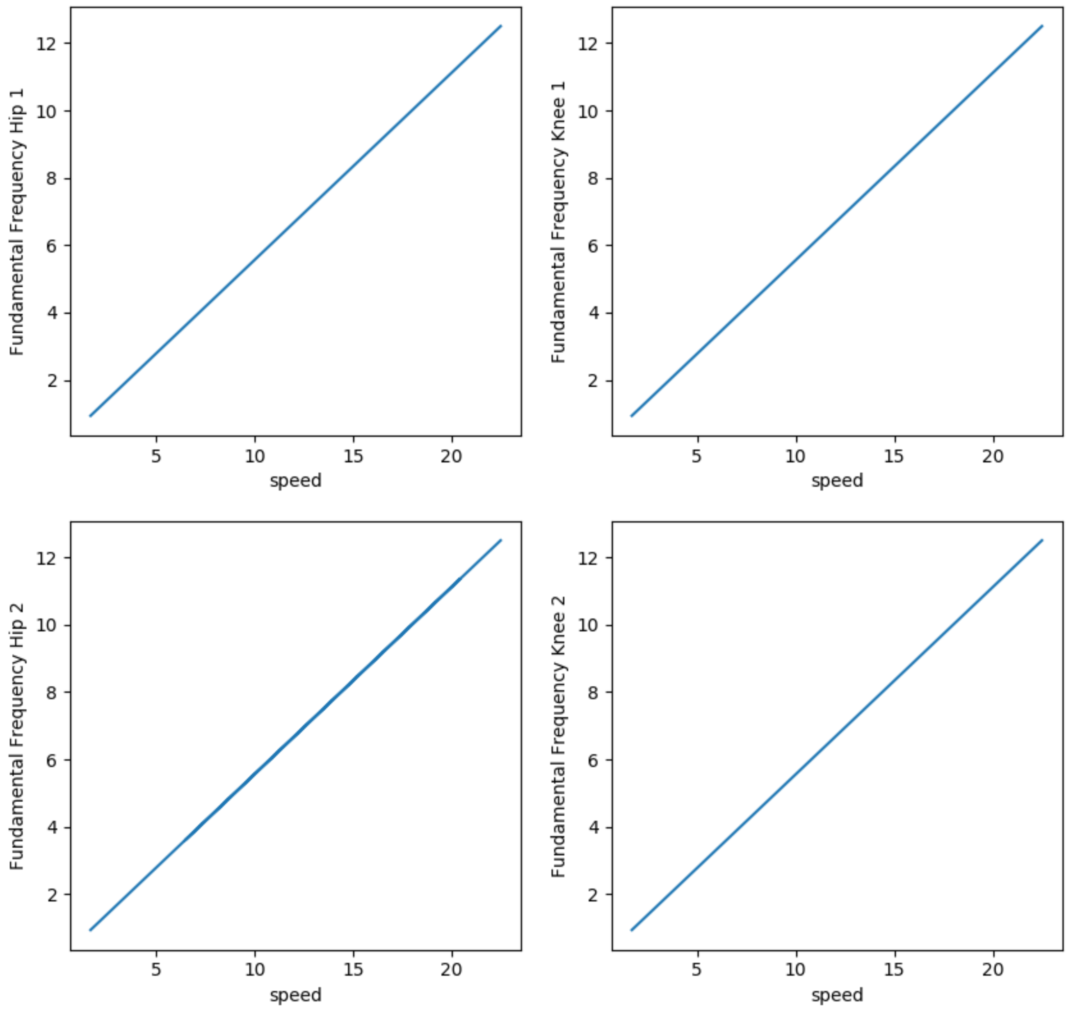
The output MLP which generates the control signals for the actuation of the joint servos takes as input the frequency components of the signal that is to be produced.

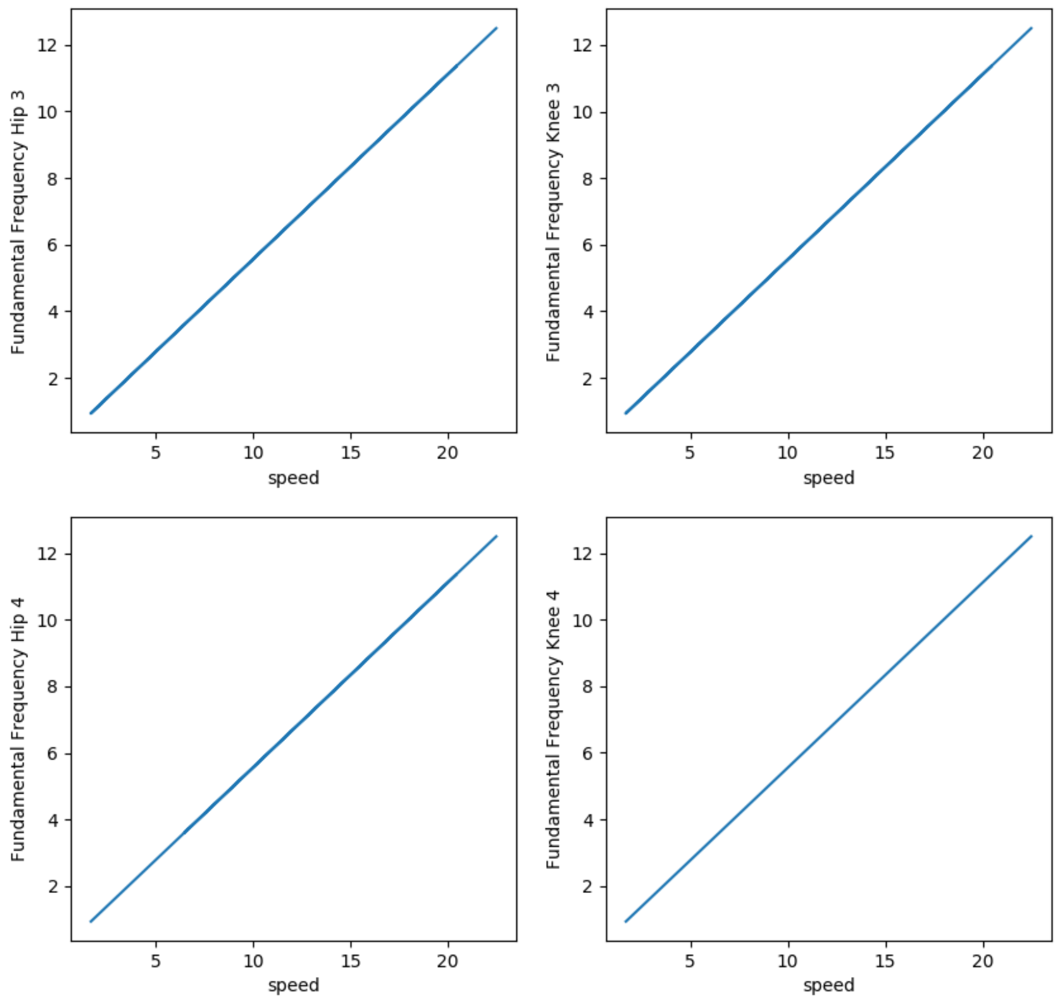
The frequency components of the signal to be produced can either be predicted by training the reservoir oscillatory neurons separately or by using integer multiples of the fundamental frequencies of the required signal. The choice between the depends on the relationship between the speed of the robot to be produced by the control signals and the fundamental frequency of the output signals as suggested in previous work.

The analysis can be summarised by the following plots between speed v, stance period T_{st}, swing period T_{sw} , magnitude of joint angle oscillation θ and the fundamental frequency f_0 of the output signal

v vs f_0

When the speed of the robot is varied by varying either T_{sw} or T_{st} and keeping θ constant, the speed follows a linear relationship with the fundamental frequency of the resultant output function. This can be seen in the following plots:





Linear Relationship can observed between the fundamental frequency for the control signal of all for legs, for both the hip and the knee joints.

According to the speed and physical motion parameter equation,

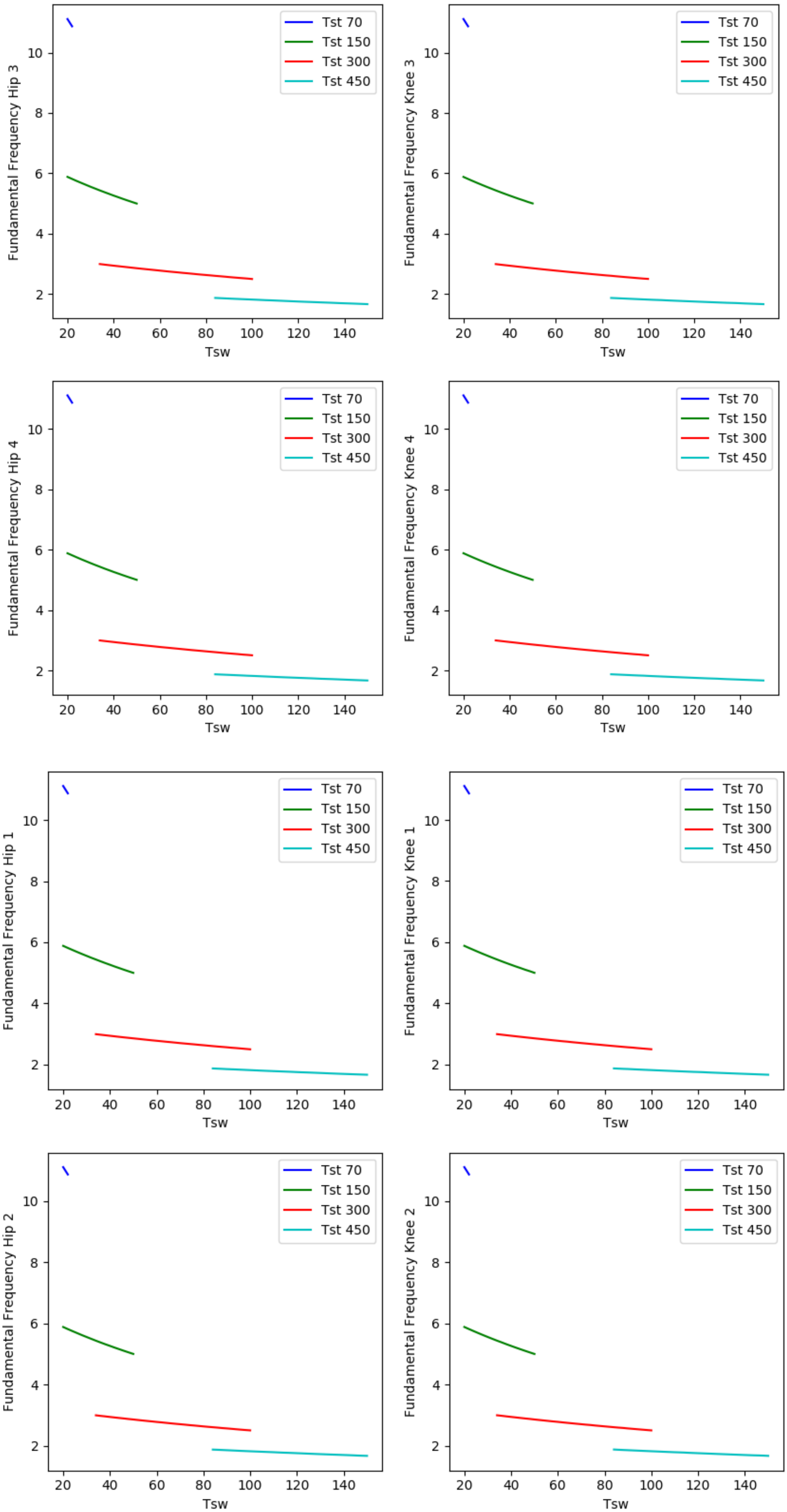
$$v = \frac{2L_T\theta_h}{T_{st} + T_{st}}$$

variation in speed of the robot can be achieved by variation of three parameters:

- θ_h
- T_{sw}
- T_{st}

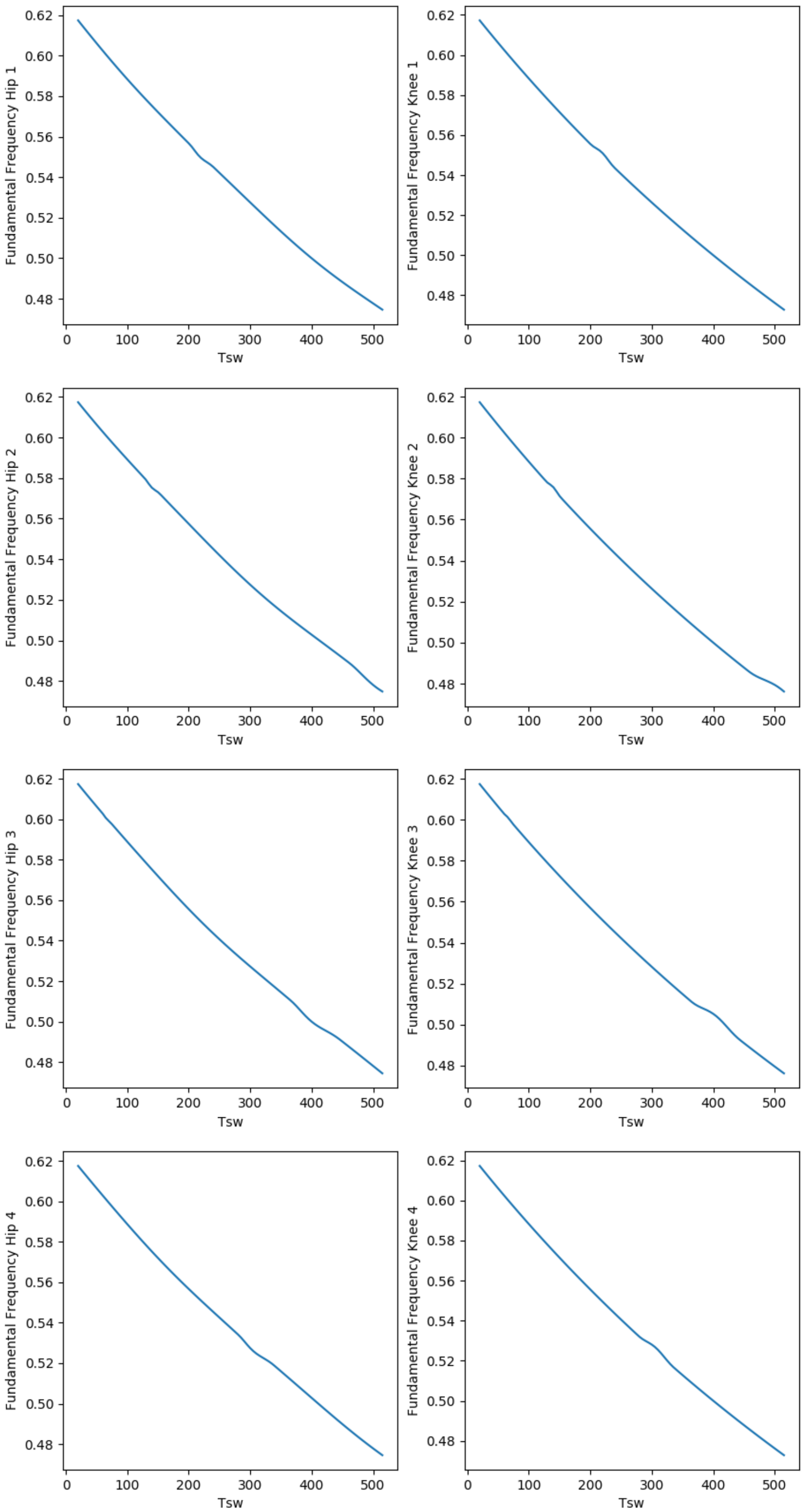
The study of the relationship between these parameters and f_0 can help better understand the underlying relationship between desired physical output and the input to the MLP

T_{sw} vs f_0



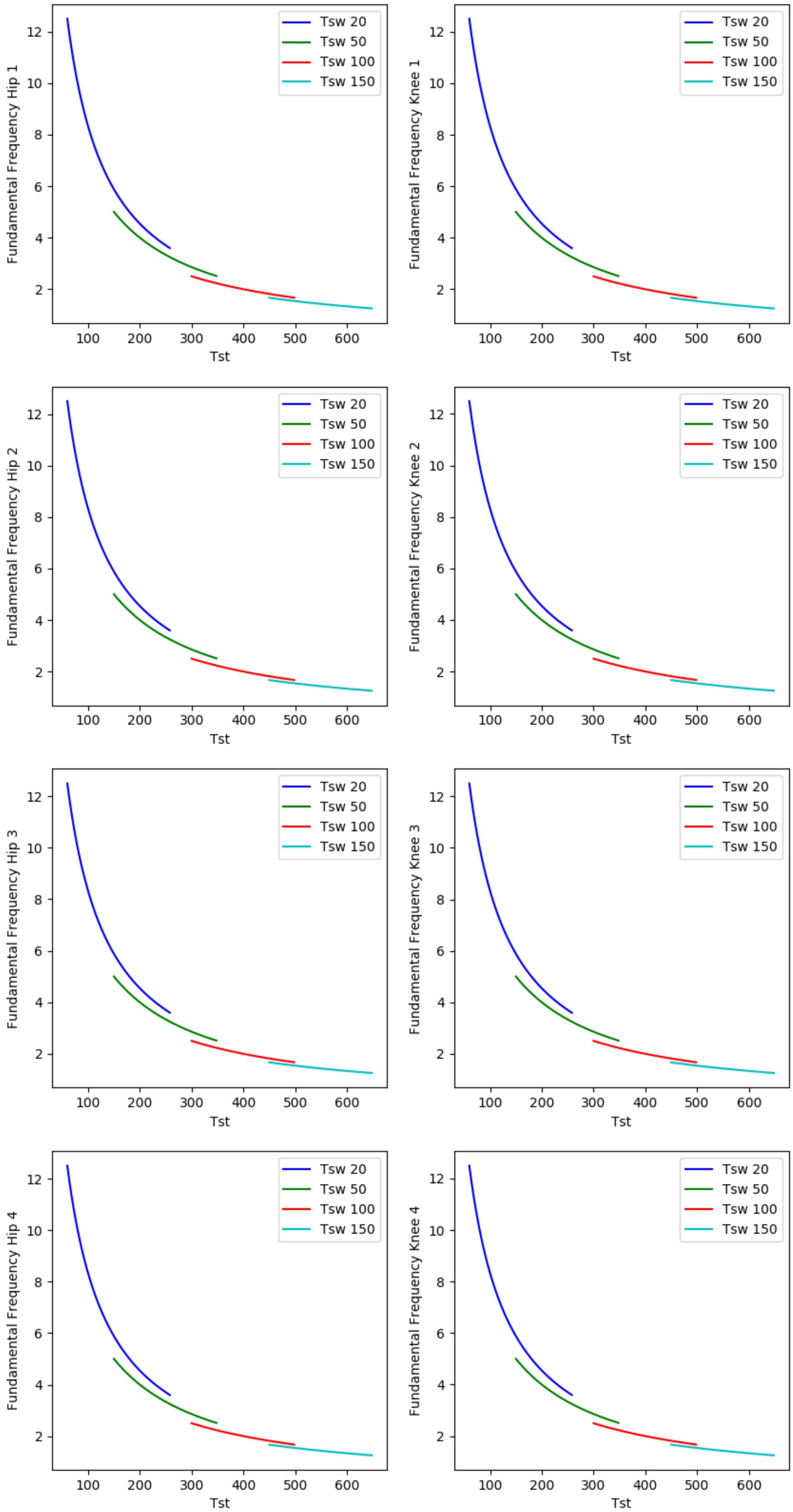
Fundamental Frequency Hip 3
Fundamental Frequency Knee 3
Fundamental Frequency Hip 4
Fundamental Frequency Knee 4
Fundamental Frequency Hip 1
Fundamental Frequency Knee 1
Fundamental Frequency Hip 2
Fundamental Frequency Knee 2
Tst 70
Tst 150
Tst 300
Tst 450
Tsw
2
4
6
8
10
20
40
60
80
100
120
140

The figures above point to a hyperbolic relationship between f_0 and T_{sw} given a fixed T_{st} and θ. All T_{sw} values are in microseconds and the fundamental frequency is in Hertz.
The following f_0 vs T_{sw} plot depicts this relationship much better. The T_{st} for this plot is set at $1500\mu s$ which results in very low speeds and thus very low fundamental frequencies.

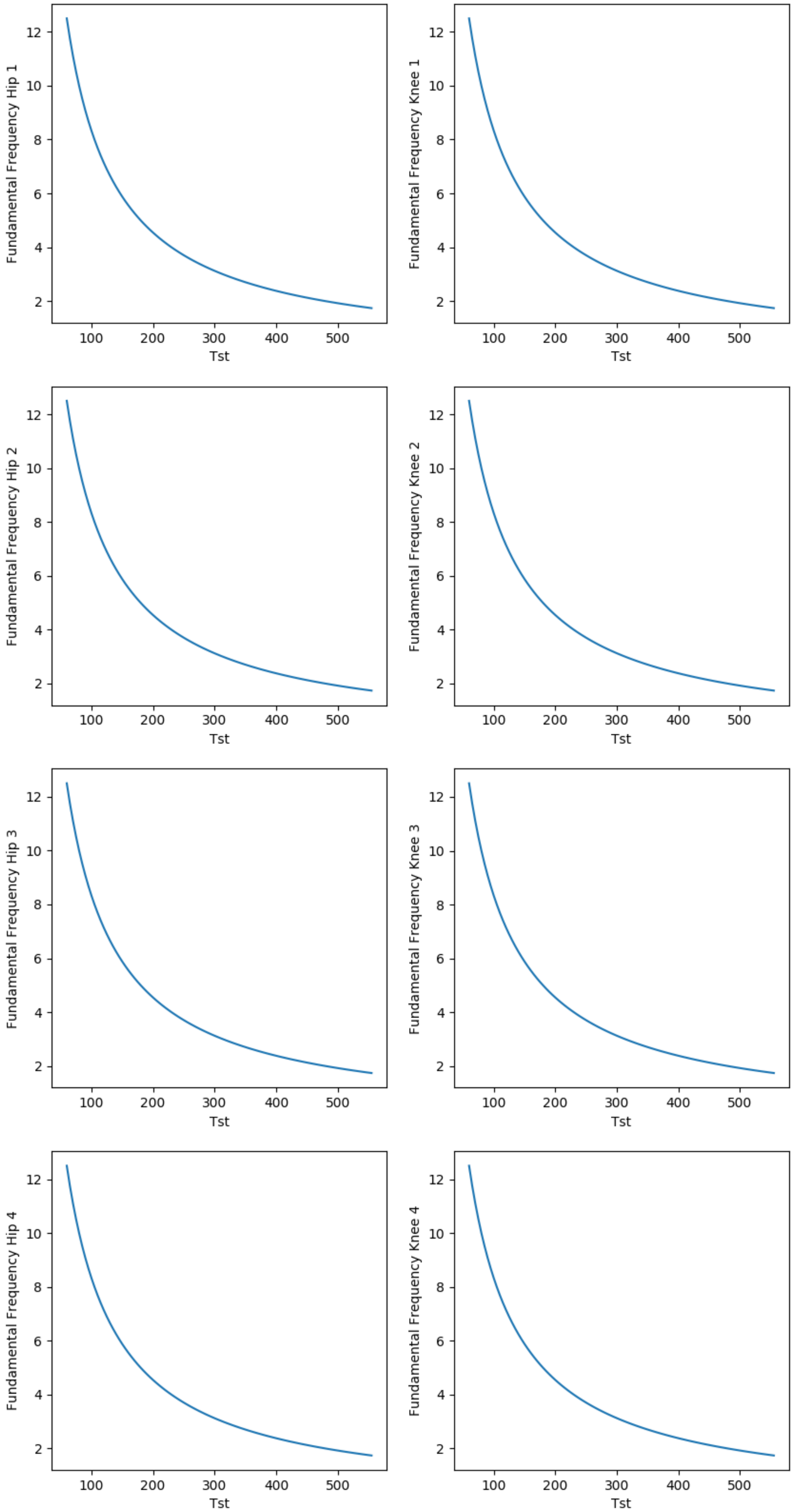


T_{st} vs f_0

The T_{st} vs f_0 curve also follows a hyperbolic trend. This hyperbolic trend is considerably more easy to spot than in the previous case of T_{sw} vs f_0 relationship. The following plots show different cases of T_{st} vs f_0 for different values of T_{sw}.

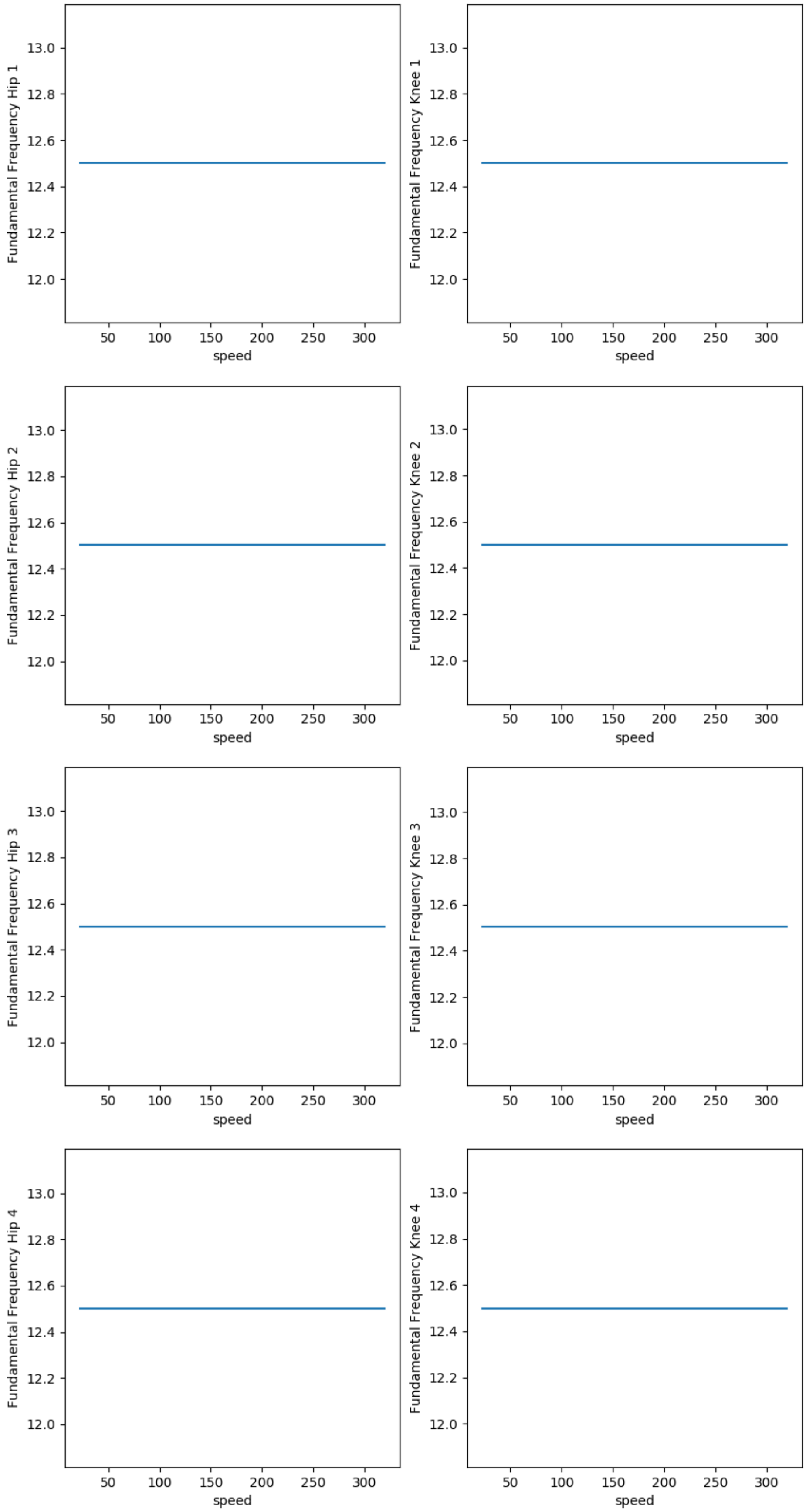


The following is the T_{st} vs f_0 plot for $T_{sw} = 15\mu s$

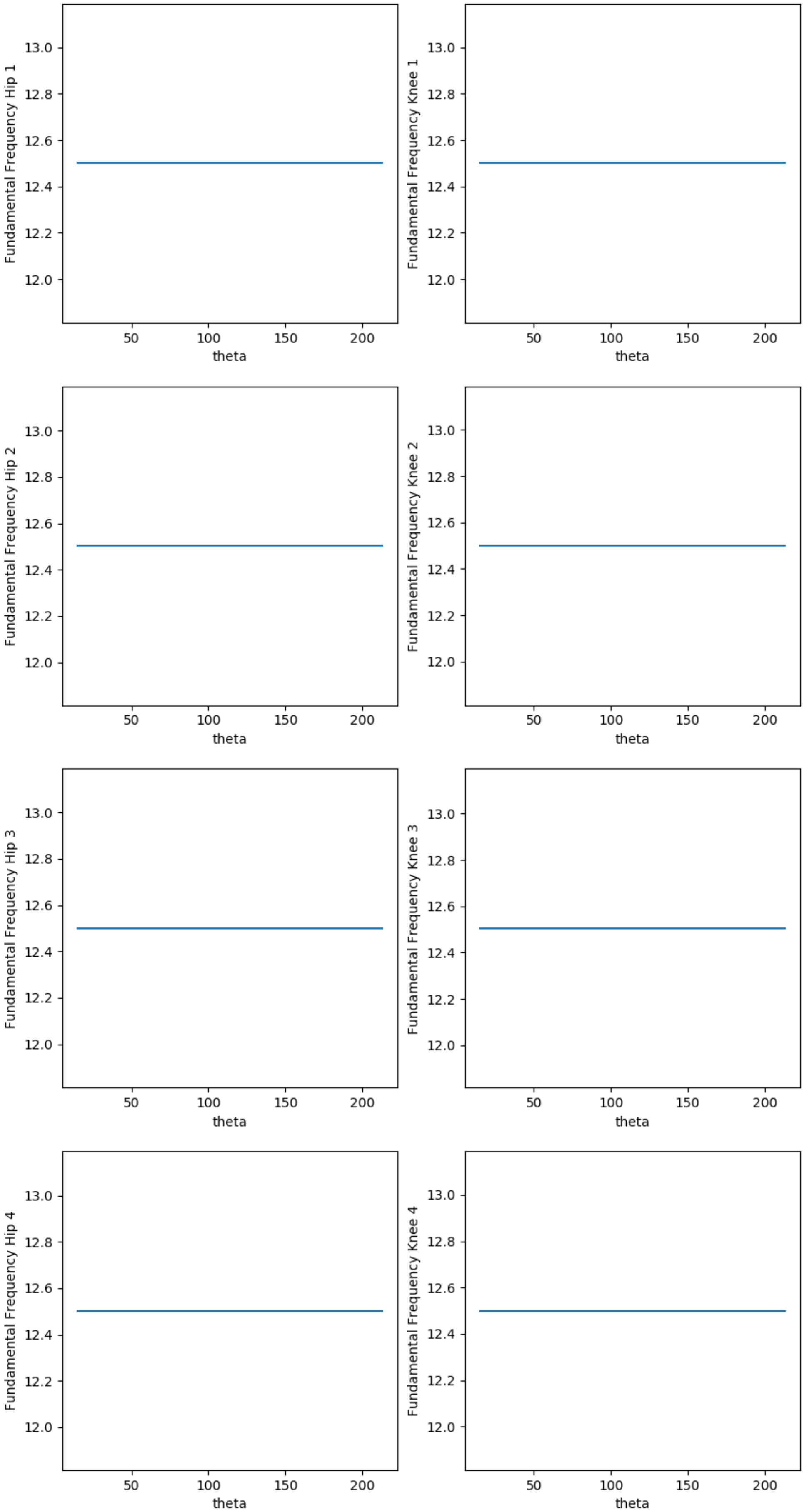


θ vs f_0

Changing the speed of the robot by changing θ has no effect on f_0.

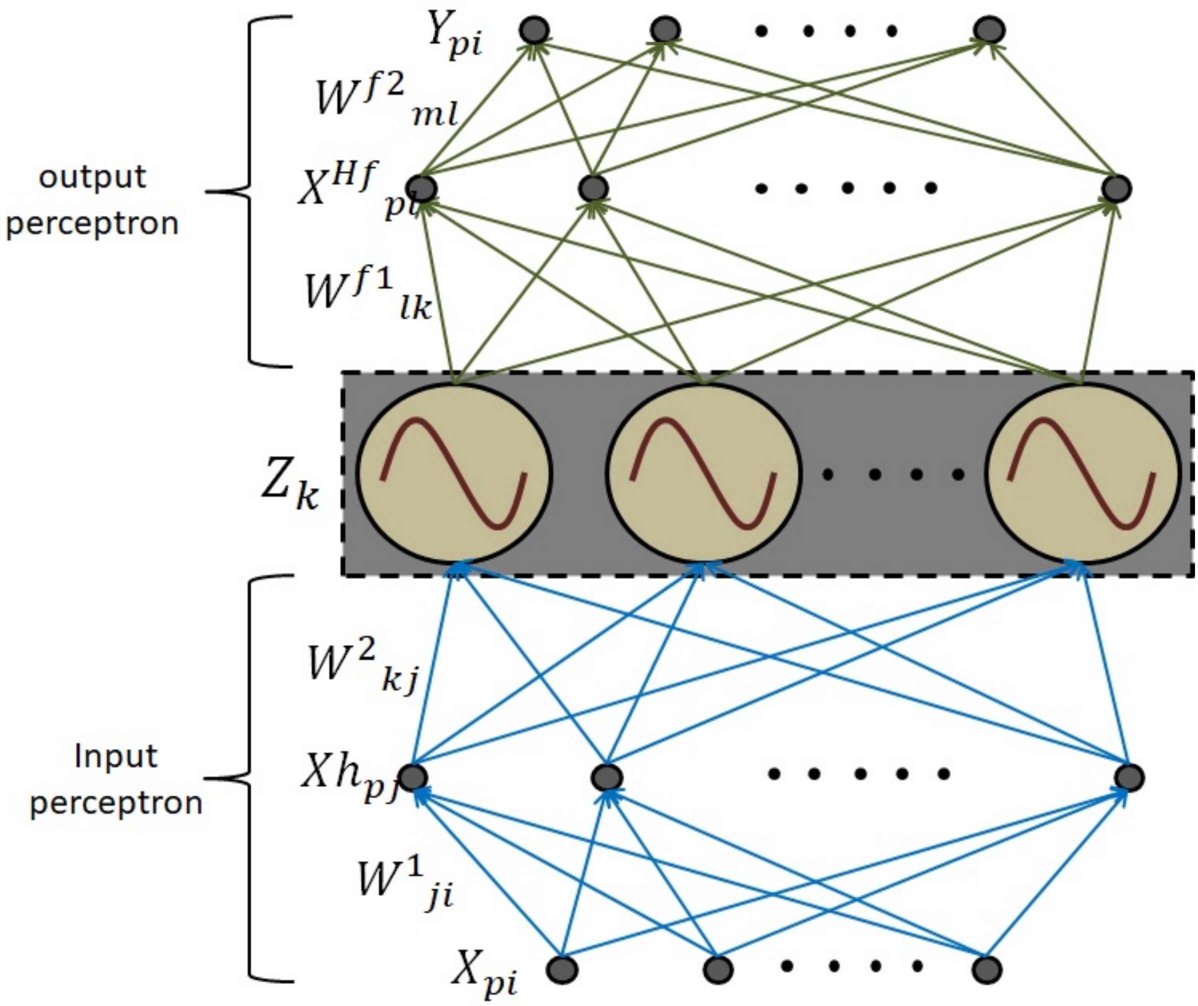


The same can be seen in the θ vs f_0 plots.



The following inference can be made from the previous plots-

- It must be noted that changes in θ are required to increase or decrease the horizontal clearance of the quadruped. Such changes will be imminent in a difficult terrain. The output MLP, which generates the the control signal has no means of identifying the need to change in the control signal when θ is modified, if integer multiples of the fundamental frequency are input to the model.
- Since the relationship between speed, θ , T_{sw}, T_{st} and f_0 do not all follow similar relationships, for the model to be identify any changes in speed, θ should also be provided as a control input to the Input MLP.
- Similar to θ, its offset from origin will determine the heading of the quadruped. The offset, also like θ, will have no effect on the fundamental frequency of the model. Thus this information will also have to be incorporated into the model.
- The fully connected real Input MLP is supposed to predict the component frequencies of the output signal. From the previous conclusions, it may be inferred that it may not be necessarily be able to change the output signal as required because the θ and its offset effect the magnitude of the constituent signals and not the frequency components.
- Moreover, to be able to produce turning motion, the model has to either change the offset of one or more legs or change the frequency of oscillation of one of more legs. Given the current end to end model, only one of the methods can be utilised for turning.
- The plots obtained can be used as a validation of the assumptions made for the derivation of the gait generation formulae shared previously.



The End-to-End MLP Model discussed above