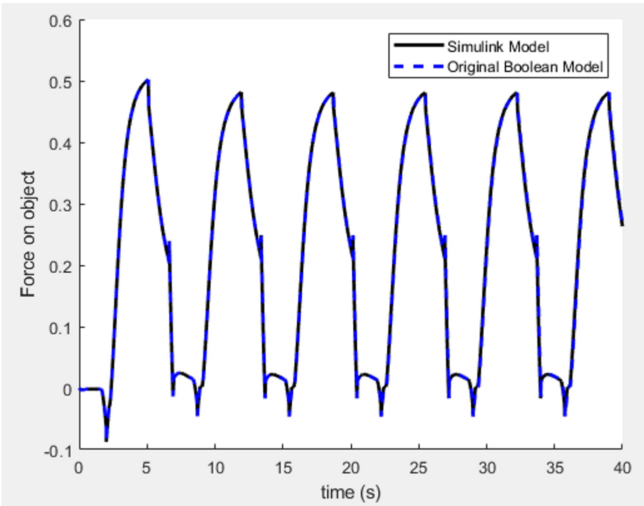
I2 Muscle Model

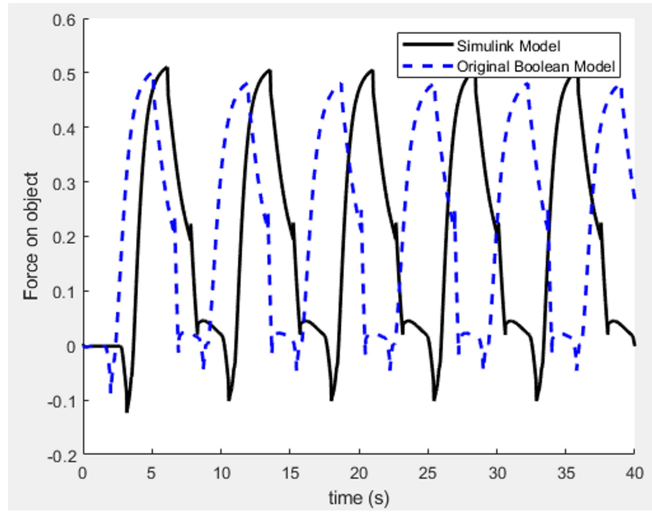
Friday, December 4, 2020 9:47 PM

Behavior when the I2 muscle force is modeled as a Hill-Type muscle

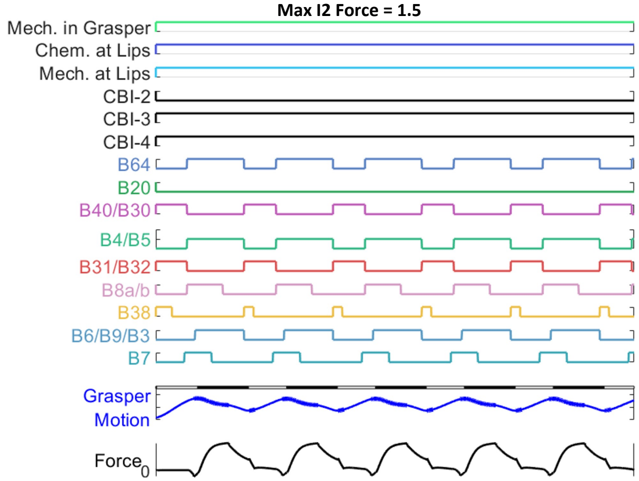
Swallow behavior: Original Force Model



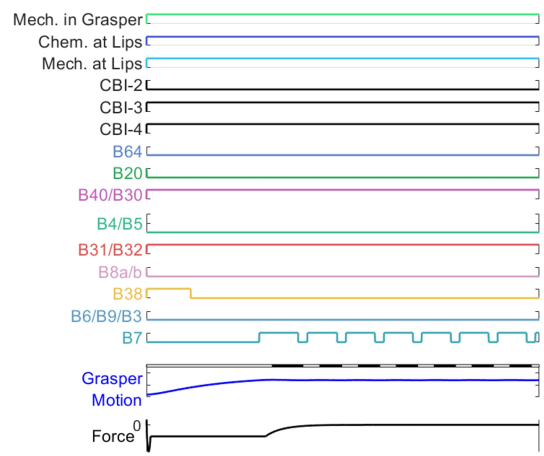
Swallow behavior: Yu Type Hill Muscle Model



Swallow behavior: Yu Type Hill Muscle Model
Max I2 Force = 1.5



Swallow behavior: Yu Type Hill Muscle Model
Max I2 Force = 0.150



Note:

- x_{gh} is scaled by the following relationship to provide the change in muscle length, l:

  $l = l_{mto}\left(1 - \frac{x_{gh}}{k}\right)$

  where l_{mto} is the optimum muscle-tendon length for the I2 Muscle and $k = 2.68$ is the scale factor to match the usable length of the passive+active force length relationship of the I2 Muscle model (0.627 to 1) to x_{gh} (0 to 1).
  - This neglects the eccentric force enhancement

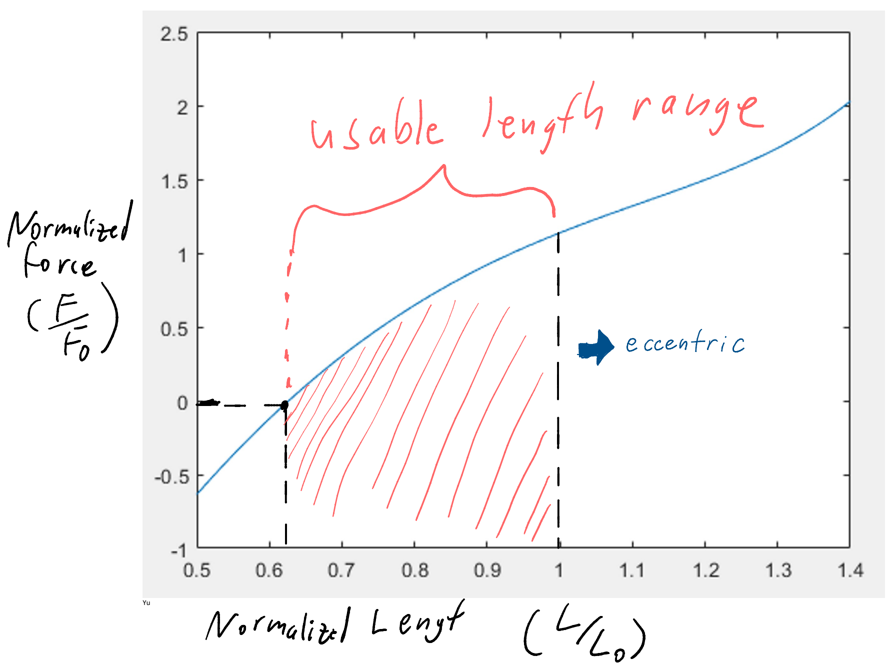
- With the original simulink implementation and timestep = 0.001 s, the compute force on object closely follows the original boolean model. When the I2 muscle model is replaced with the Yu Type Hill Type Muscle Model, there appears to be a time shift in the computed force relative to the original boolean model, but the shapes are similar

- The Yu Type Hill Type Muscle Model uses an isometric maximum force, $F_0 = 0.150\ N$. If this scale factor is not changed, the periodic feeding behavior is not observed. If it is changed to 1.5 to match the original value for max_I2, the periodic feeding behavior is observed.

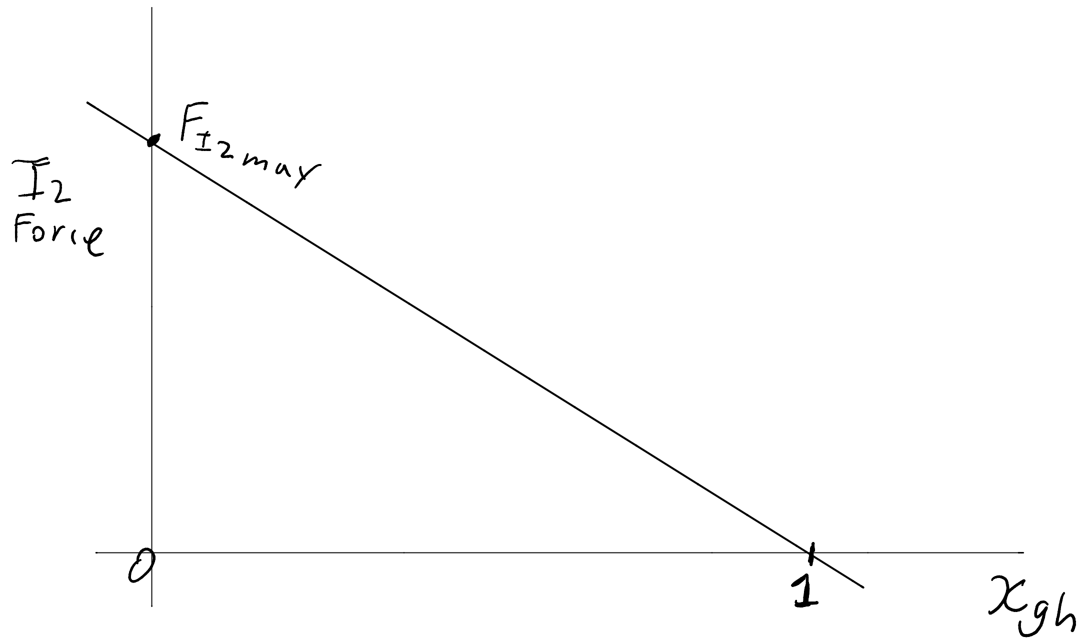
Hill-Type muscle model compared to Boolean Model's I2 Muscle Force

Hill-Type muscle model shows decreasing force output with decreasing length. Boolean Model shows decreasing force output with increasing x_{gh}

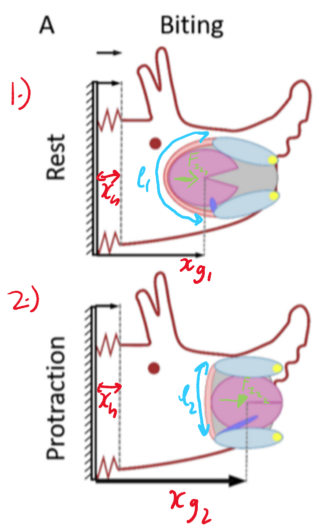
Yu Hill Type Muscle Model: Passive + Active Force - Length relationship

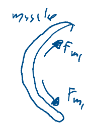


Boolean Model I2 Muscle Force

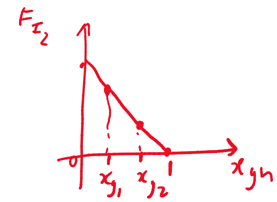


Relationship between muscle force and I2 force on Grasper? Relationship between muscle length and x_{gh}?

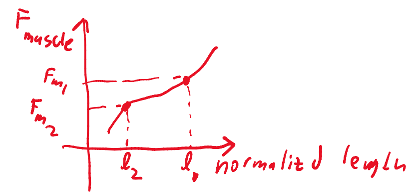




$x_{g_1} < x_{g_2}$ ∴ $F_{I_{2_1}} > F_{I_{2_2}}$



$l_1 > l_2$ ∴ $F_{m_1} > F_{m_2}$



So when $x_{g_2} > x_{g_1}$ $\begin{cases} F_{I_{2_1}} > F_{I_{2_2}} \\ F_{m_1} > F_{m_2} \end{cases}$

so $F_m \propto F_{I_2}$

Now assume $F_m(l) = F_{I_2}(x_{gh})$ . . . (is this valid ?)

then $l = f(x_g)$

we want to express l (musle length input to Hill type model) as function of as function of x_{gh} to Hill type model)

Based on plots of Yu muscle length relationship and the boolean model force - x_{gh} relationship, one possible relationship is:

$$k\left(c + \frac{l}{l_{mto}}\right) = x_{gh}$$

we want $F_m(x_{gh} = 0) = \frac{F_{max}}{F_o} = 1$

and $F_m(x_{gh} = 1) = 0$

from active muscle length relationship, F_{max} occurs at $l = l_{mto}$ and $x_{gh} = 0$, so:

$$k(c+1) = 0$$

$$c = -1$$

from total muscle-length relationship, $F_m = 0$ @ $0.627\, l_{mto}$ and $x_{gh} = 1$

So $k(0.627 - 1) = 1$

$$k = -2.681$$

So

So

$$l = l_{mto}\left(\frac{x_{gh}}{k} - c\right)$$

$$l = l_{mto}\left(\frac{x_{gh}}{-2.68} + 1\right)$$

$$l = l_{mto}\left(1 - \frac{x_{gh}}{2.68}\right)$$