An agonist-antagonist pitch production (A2P2) model

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Outline

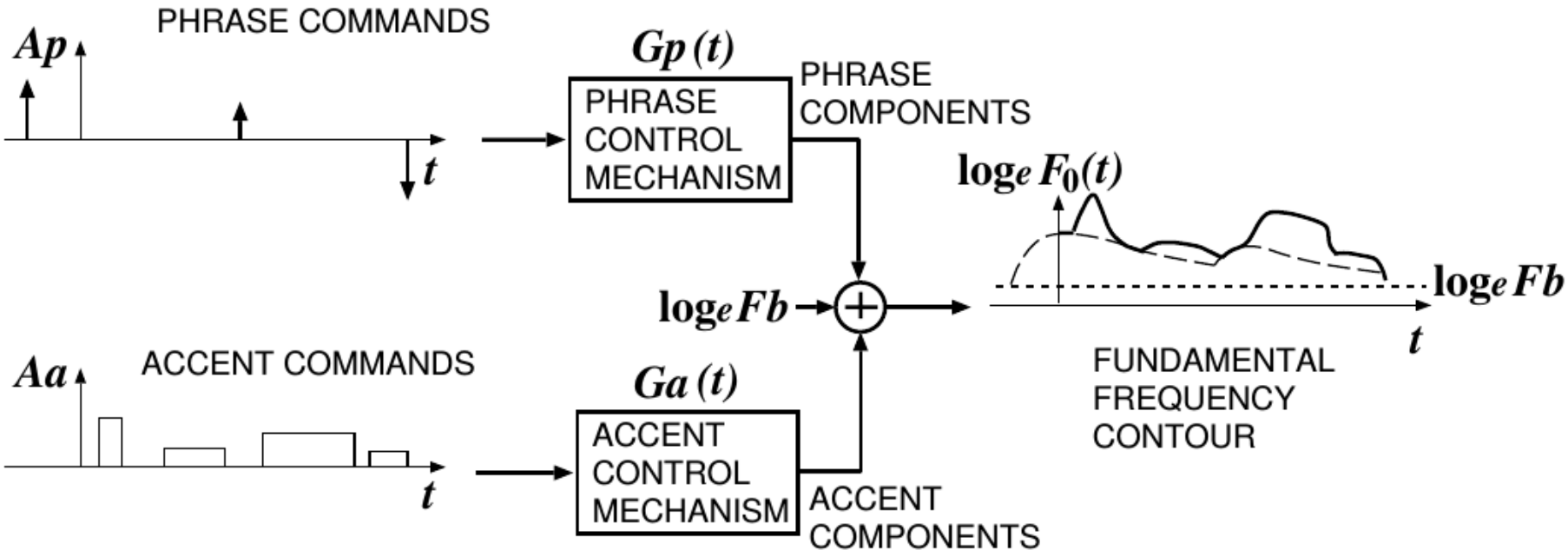
- Introduction
- SDM and Hill type models
- Agonist-antagonist pitch production model
- Conclusions

Introduction

- Prosody modelling is crucial for a number of speech technologies: TTS, SER, ASR ...
- A lot of intonation models have been proposed:
  - Surface F0 models: ToBI, INSINT, IViE, Tilt, SFC ...
  - Physiological F0 models: CR, StemML, qTA ...

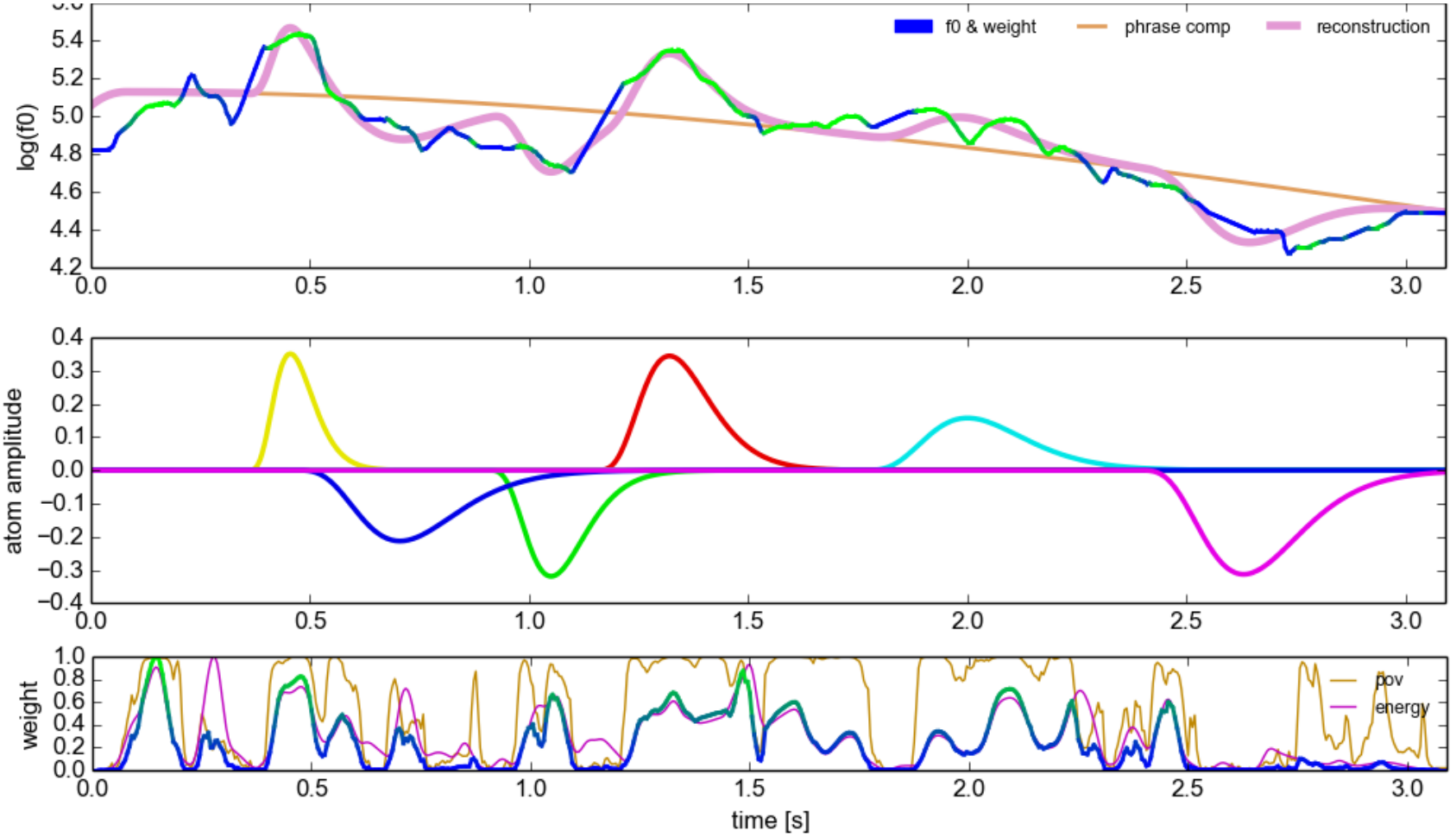
Introduction

- Fujisaki's Command Response model

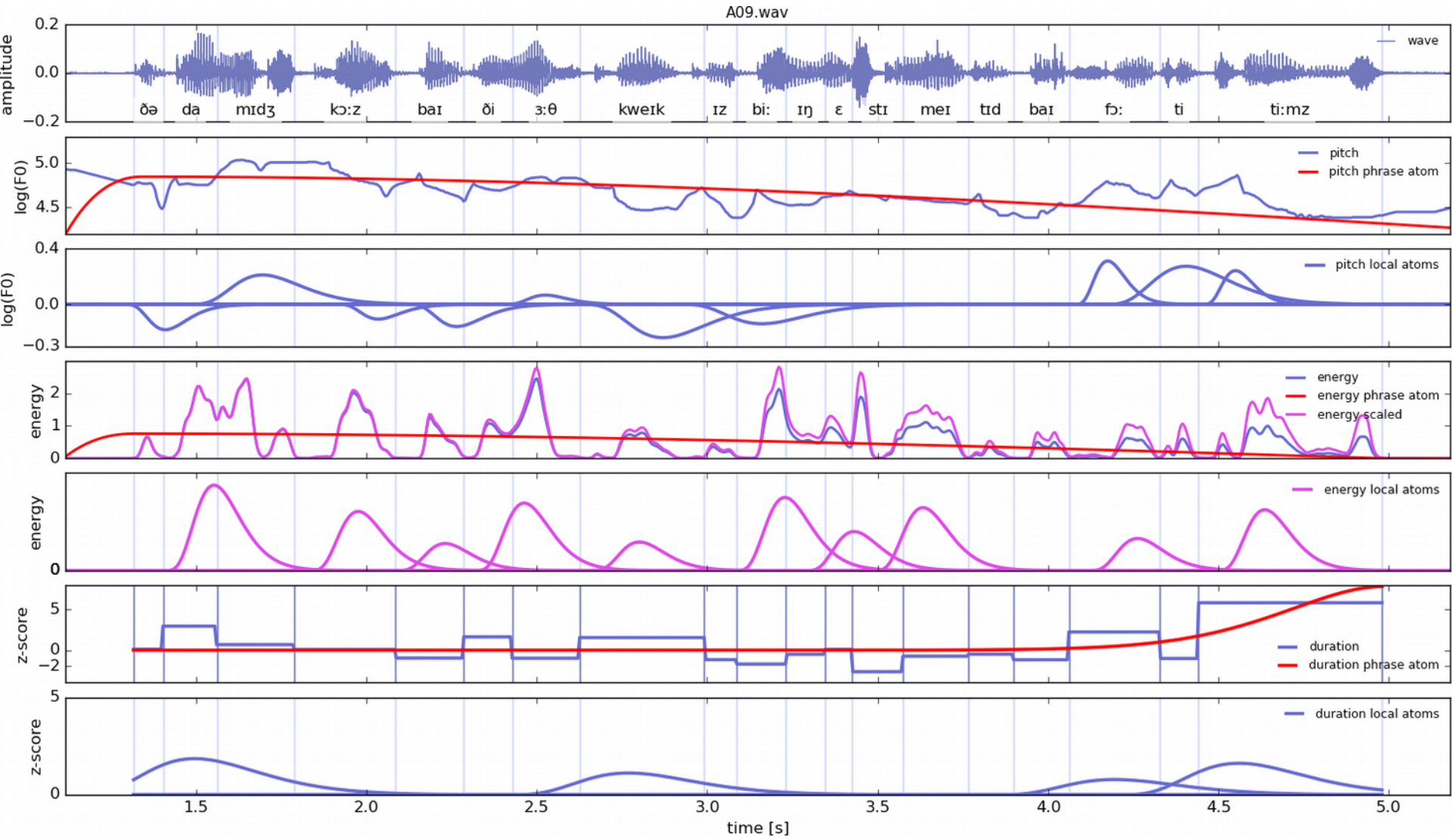


Introduction

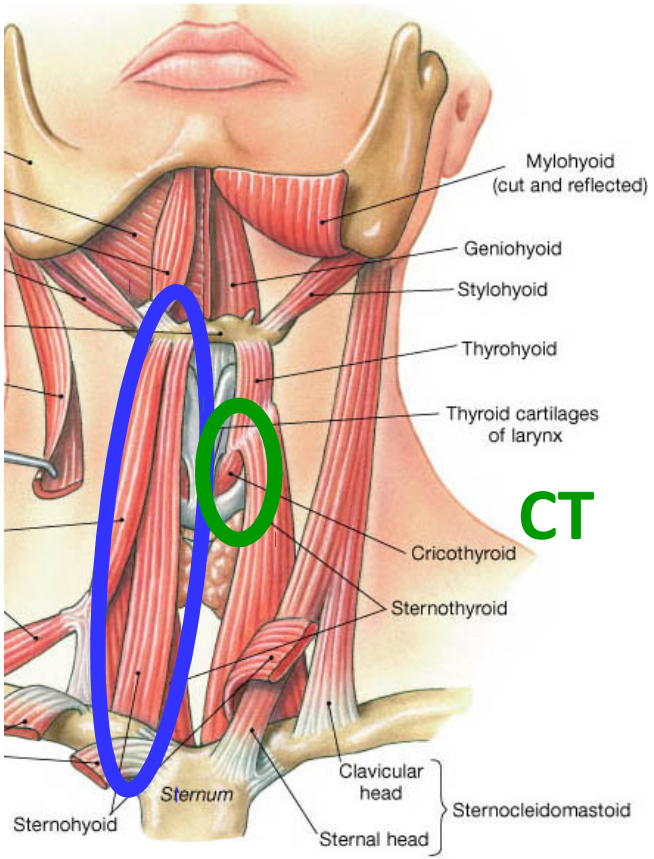
- Generalized Command Response model



Introduction

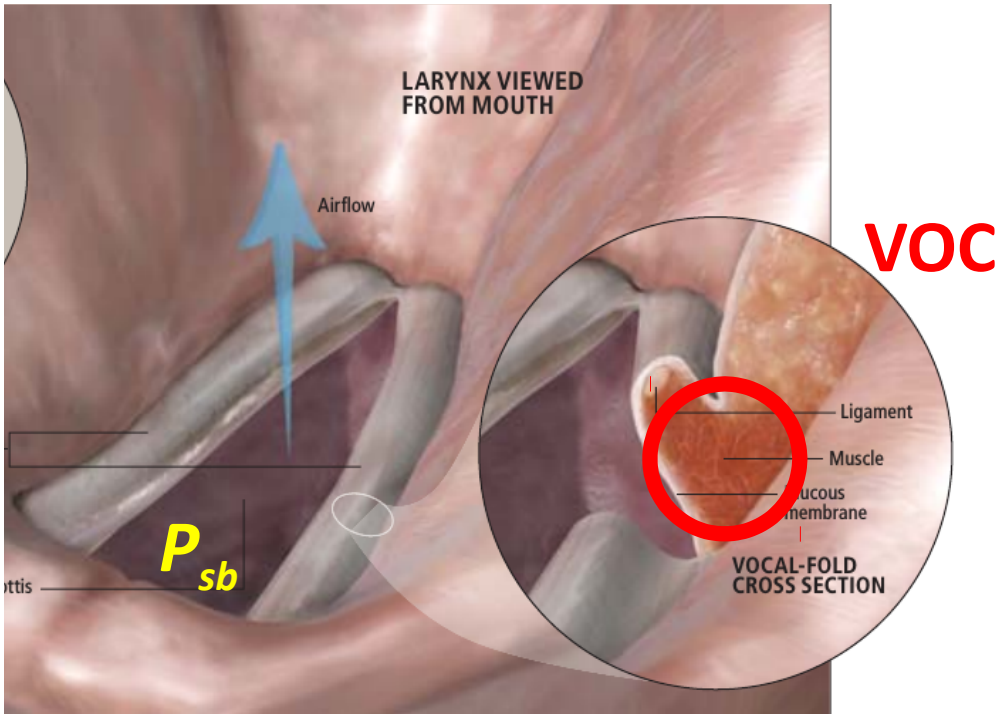


Introduction



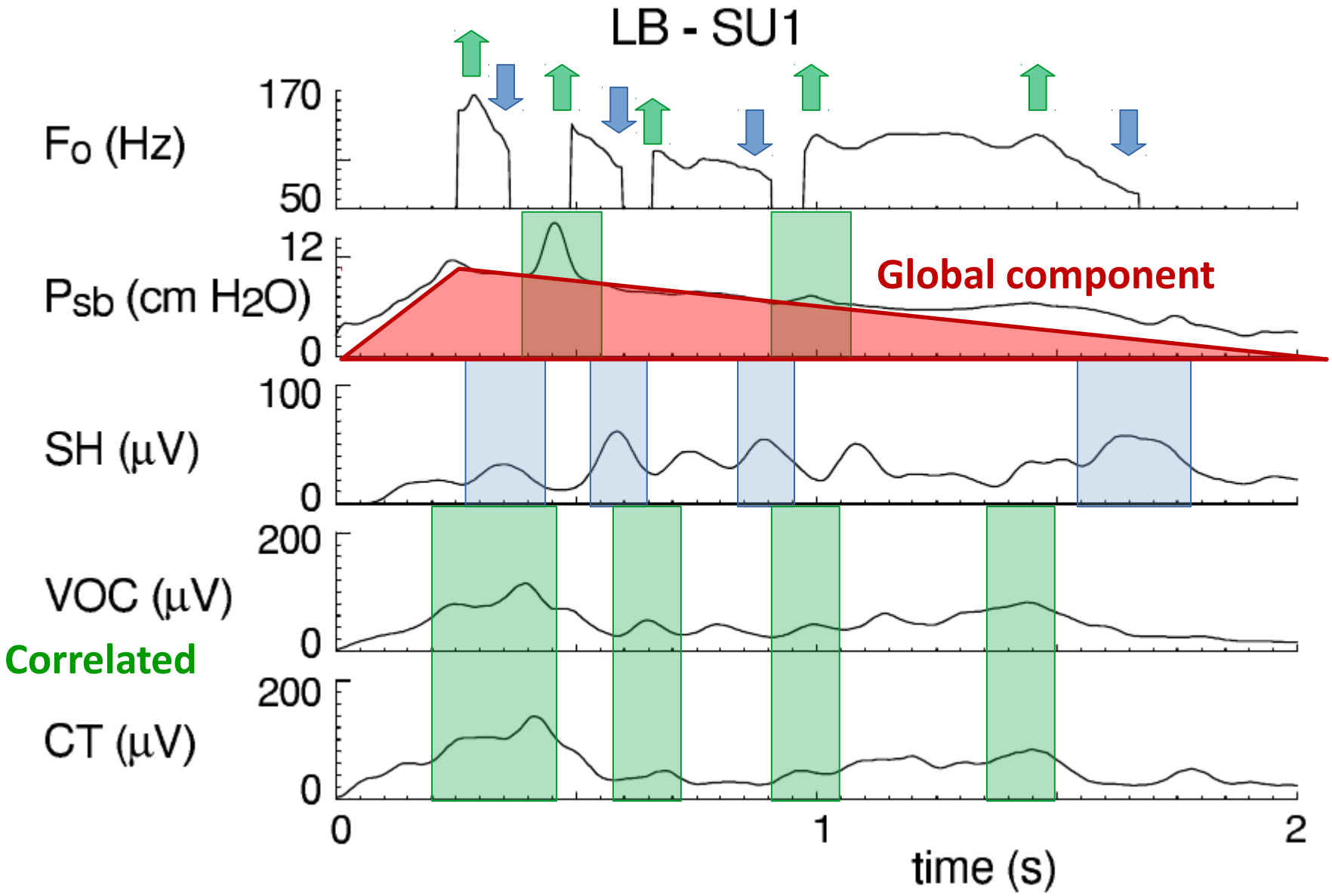
CT

SH



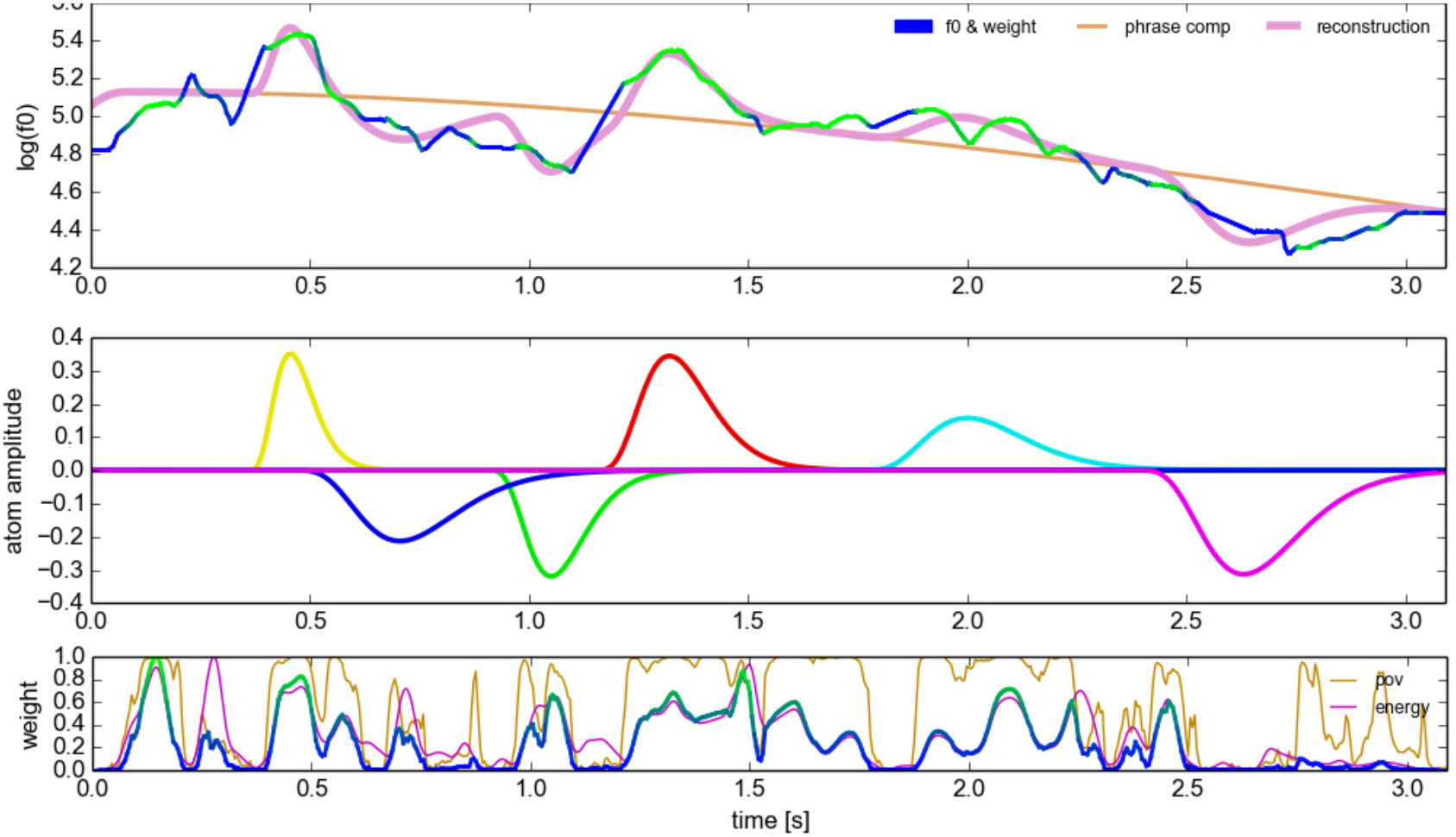
VOC

Introduction

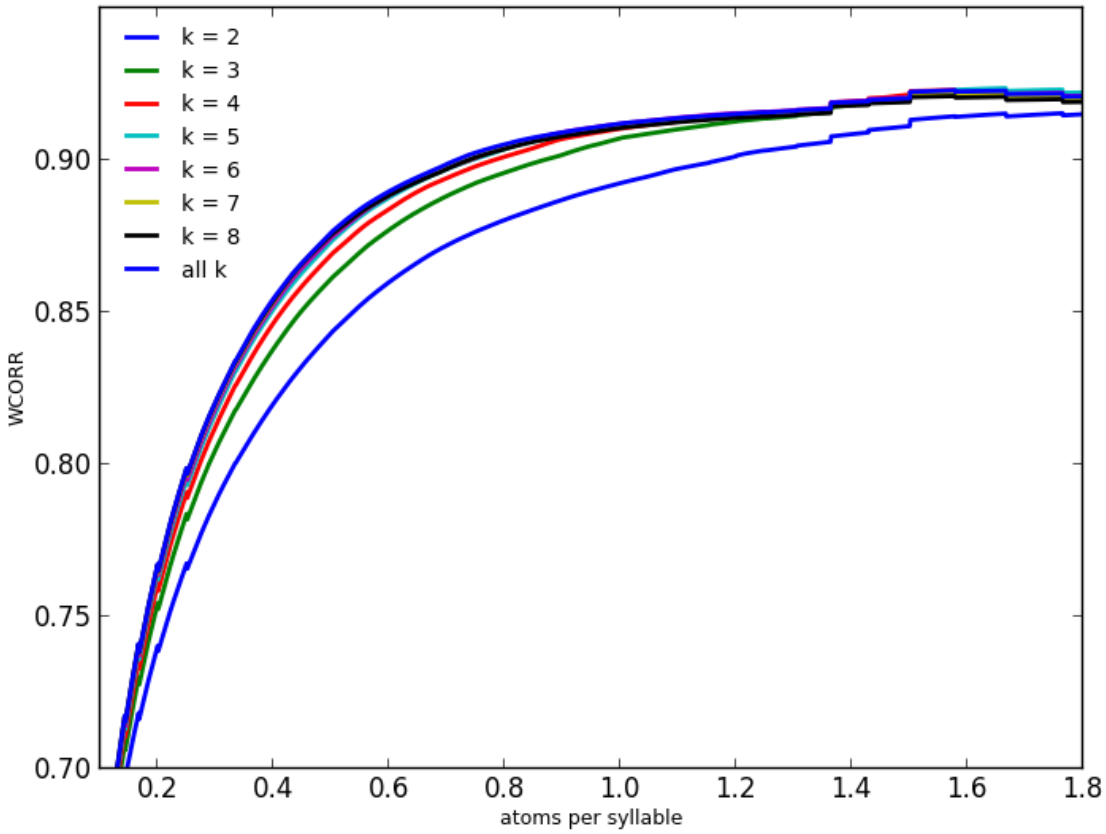


Introduction

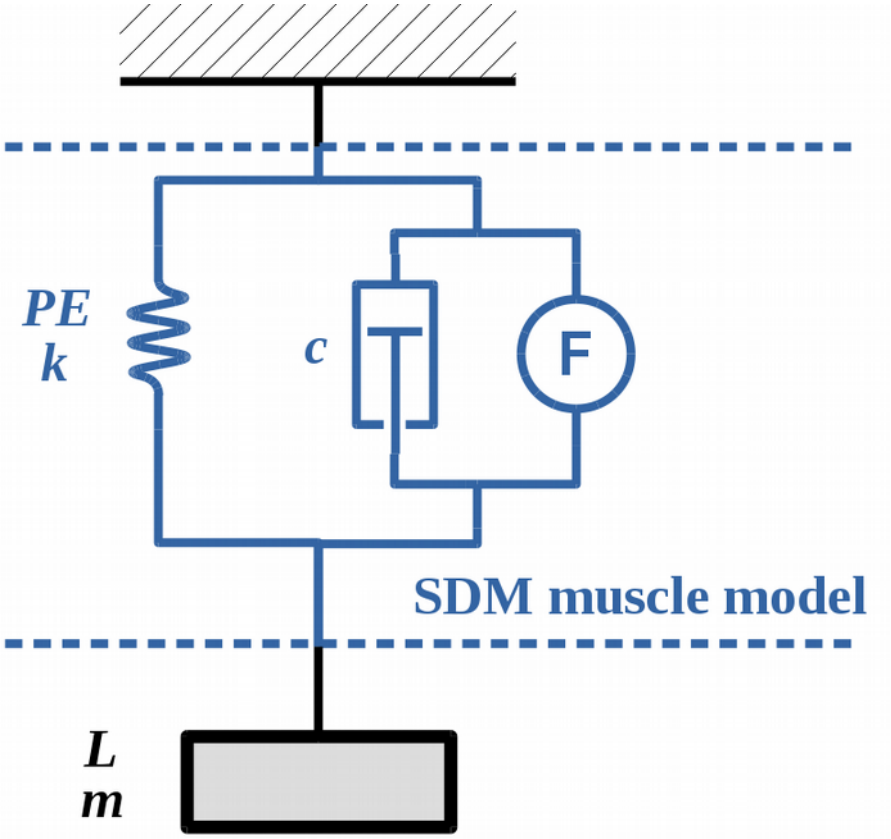
- Generalized Command Response model



Introduction



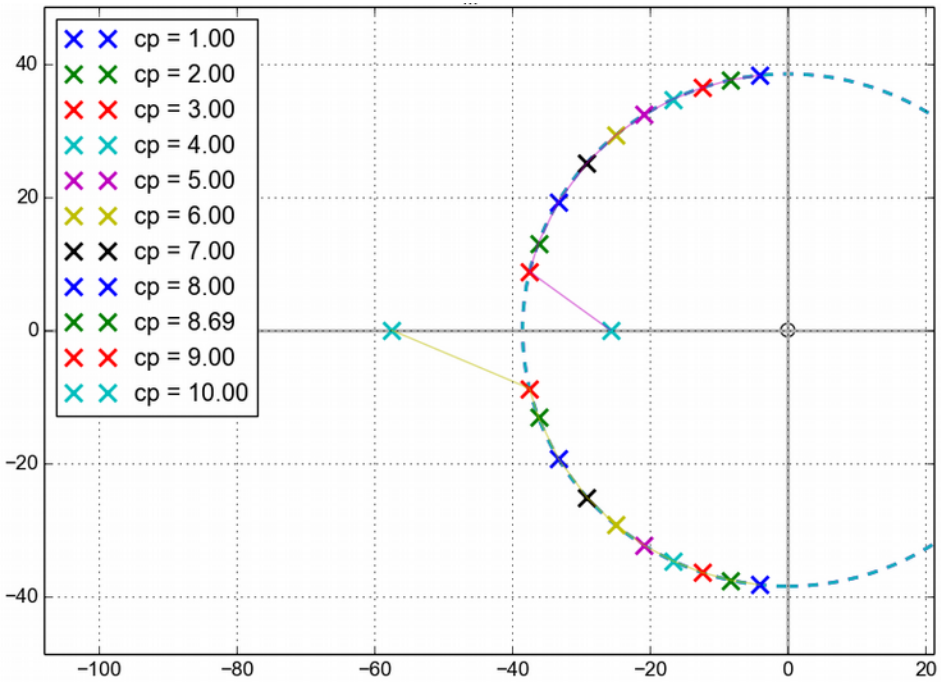
Spring Damper Mass (SDM) model



$$y(s) = \frac{1}{\frac{m}{k}s^2 + \frac{c}{k}s + 1}$$

$$\zeta^2 \triangleq \frac{c^2}{4mk} \qquad \omega_0^2 \triangleq \frac{k}{m}$$

SDM model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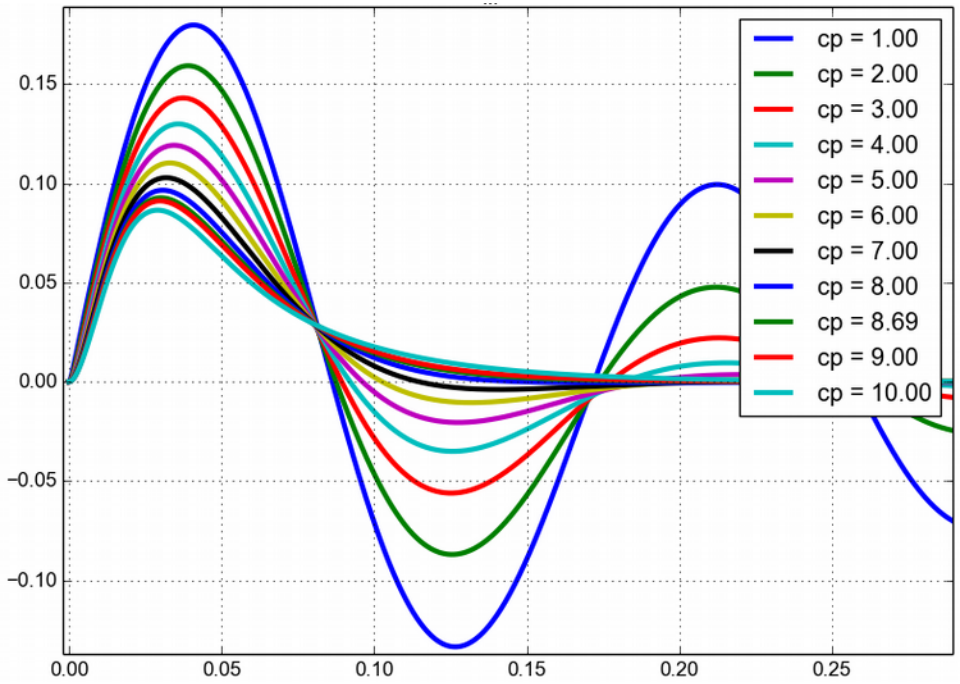
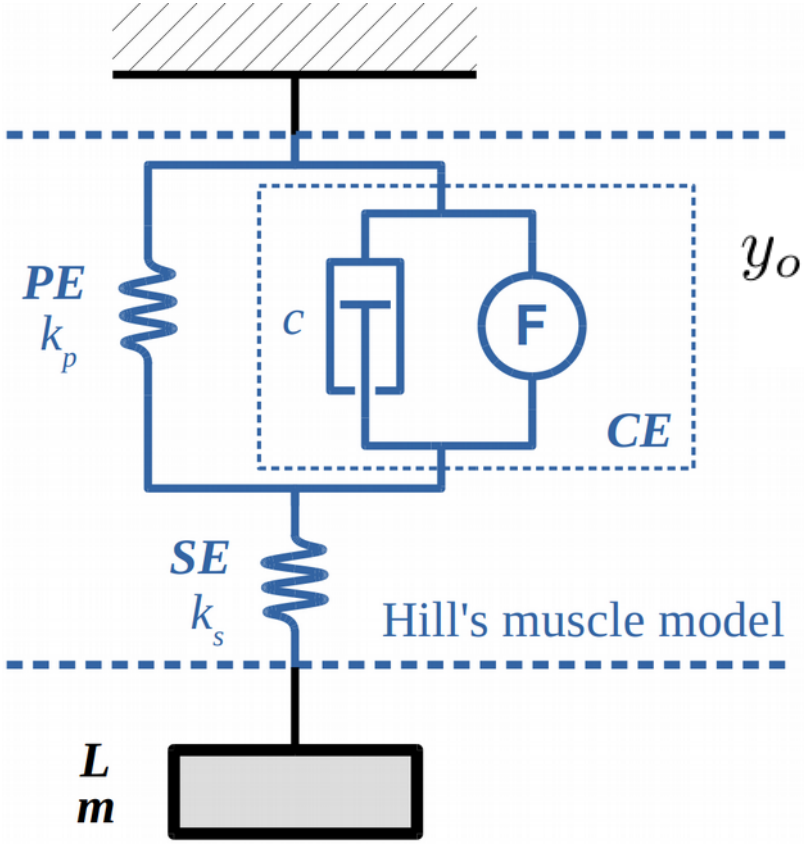
cp = 3.00
cp = 4.00
cp = 5.00
cp = 6.00
cp = 7.00
cp = 8.00
cp = 8.69
cp = 9.00
cp = 10.00
40
20
0
−20
−40
−100
−80
−60
−40
−20
0
20


cp = 1.00
cp = 2.00
cp = 3.00
cp = 4.00
cp = 5.00
cp = 6.00
cp = 7.00
cp = 8.00
cp = 8.69
cp = 9.00
cp = 10.00
0.15
0.10
0.05
0.00
−0.05
−0.10
0.00
0.05
0.10
0.15
0.20
0.25

SDM model

- The 2nd order SDM does not capture important tendon dynamics.
- It is also not physiologically plausible.

Hill type muscle model

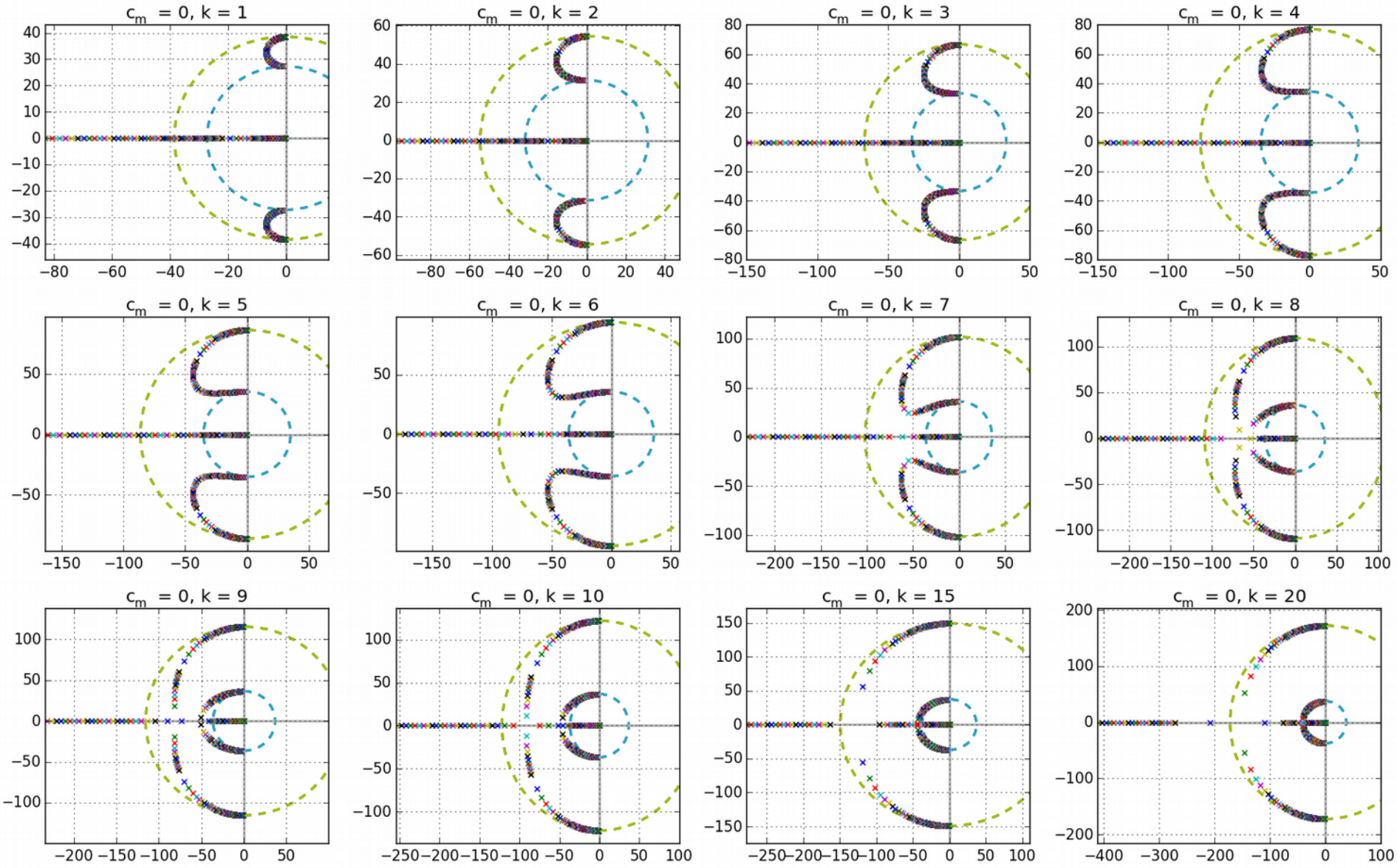


$$y_o(s) = \frac{1}{\frac{cm}{k_s}s^3 + m\frac{k_s+k_p}{k_s}s^2 + cs + k_p}$$

$$\omega_0^2 = \frac{k_p k_s}{m(k_p + k_s)}$$

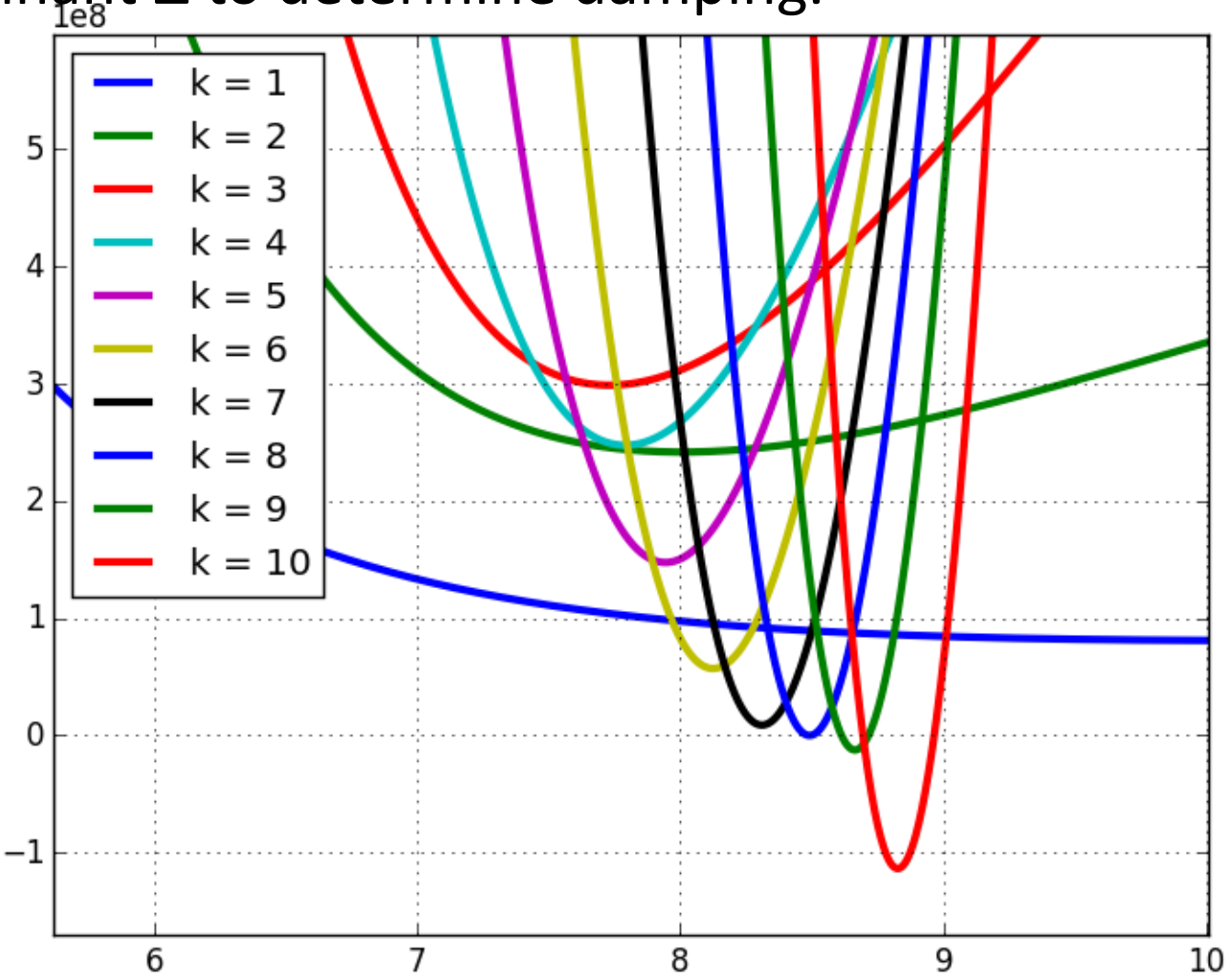
$$k = {}^{k_s}/_{k_p}$$

Hill type muscle model

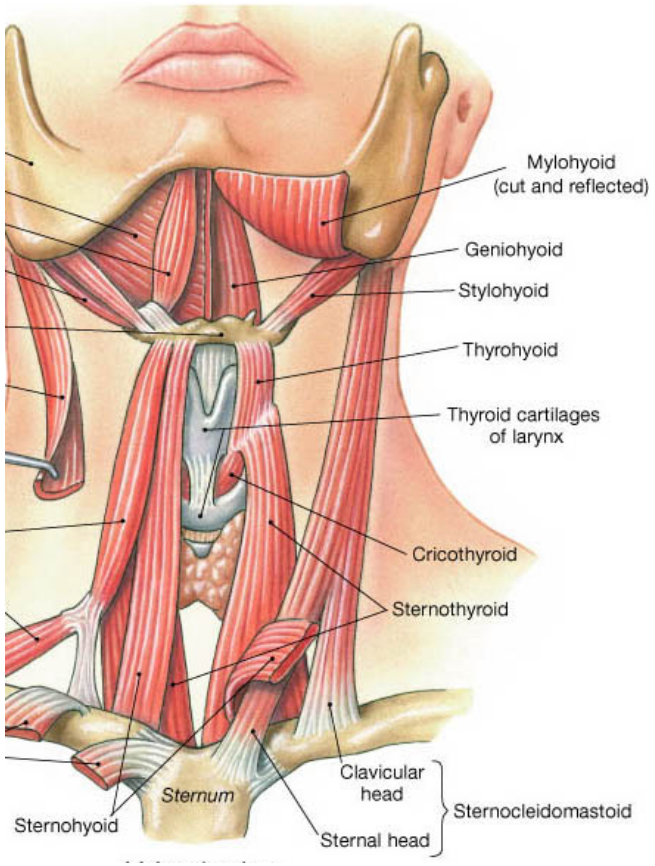


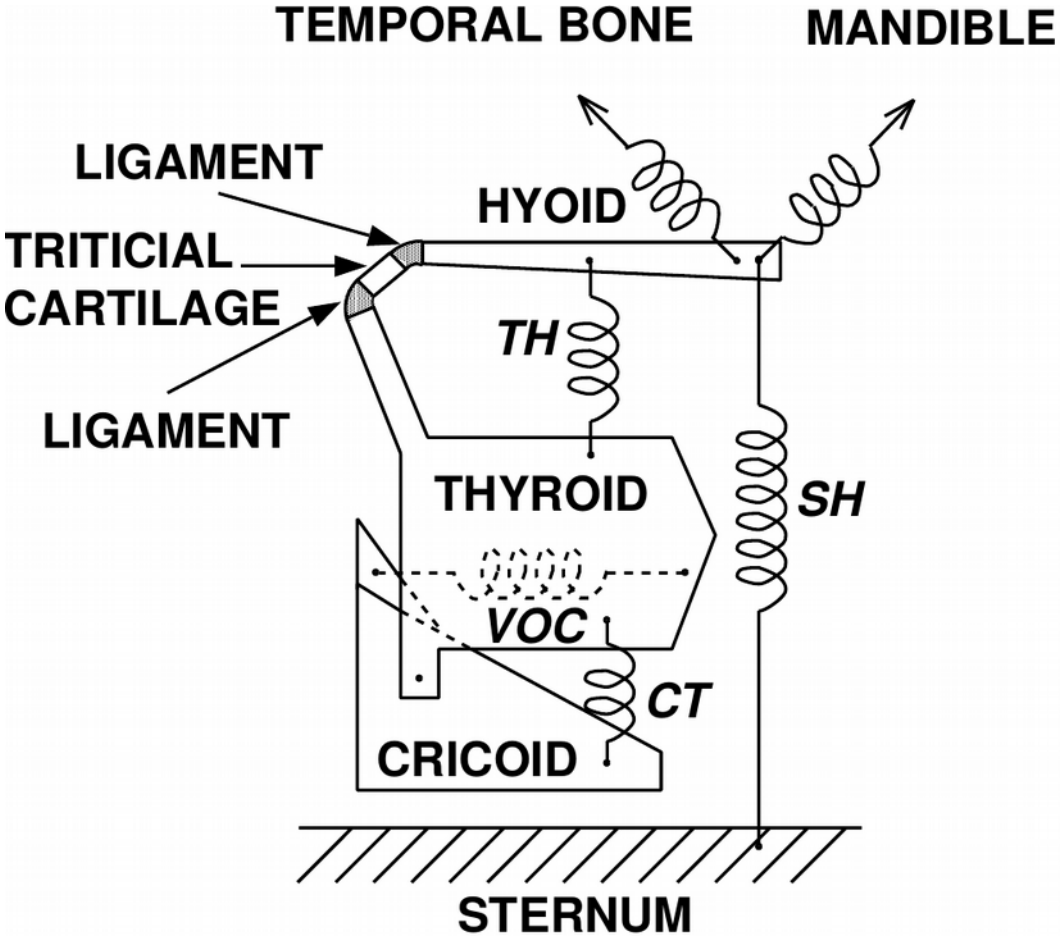
Hill type muscle model

Piovesan *et al.* 2013 used Cardano's formula and the discriminant Δ to determine damping.



Agonist-antagonist pitch production (A2P2) model



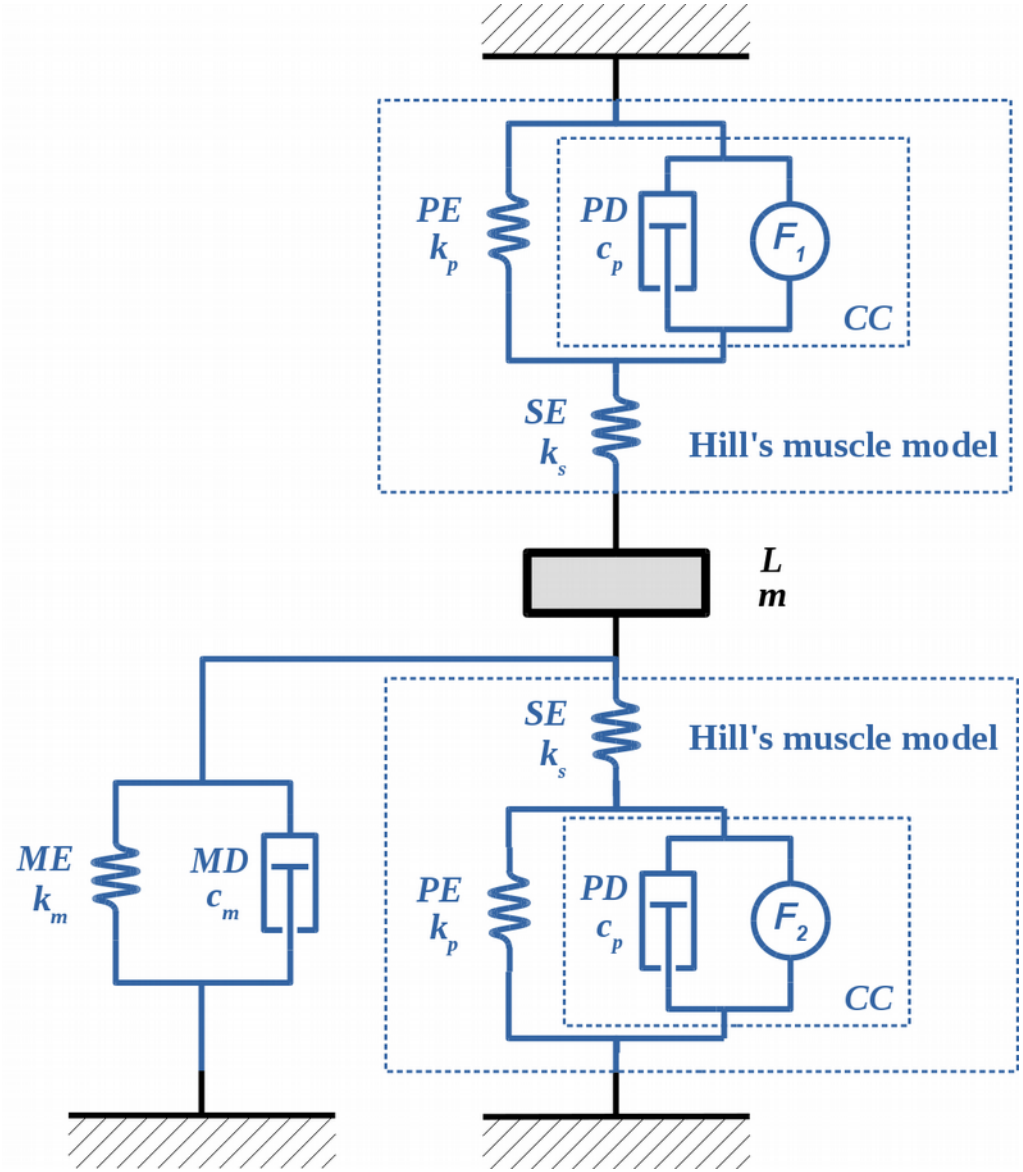


Taken from Fujisaki, H.: The roles of physiology, physics and mathematics in modeling prosodic features of speech. In: Proc. of Speech Prosody. (2006)

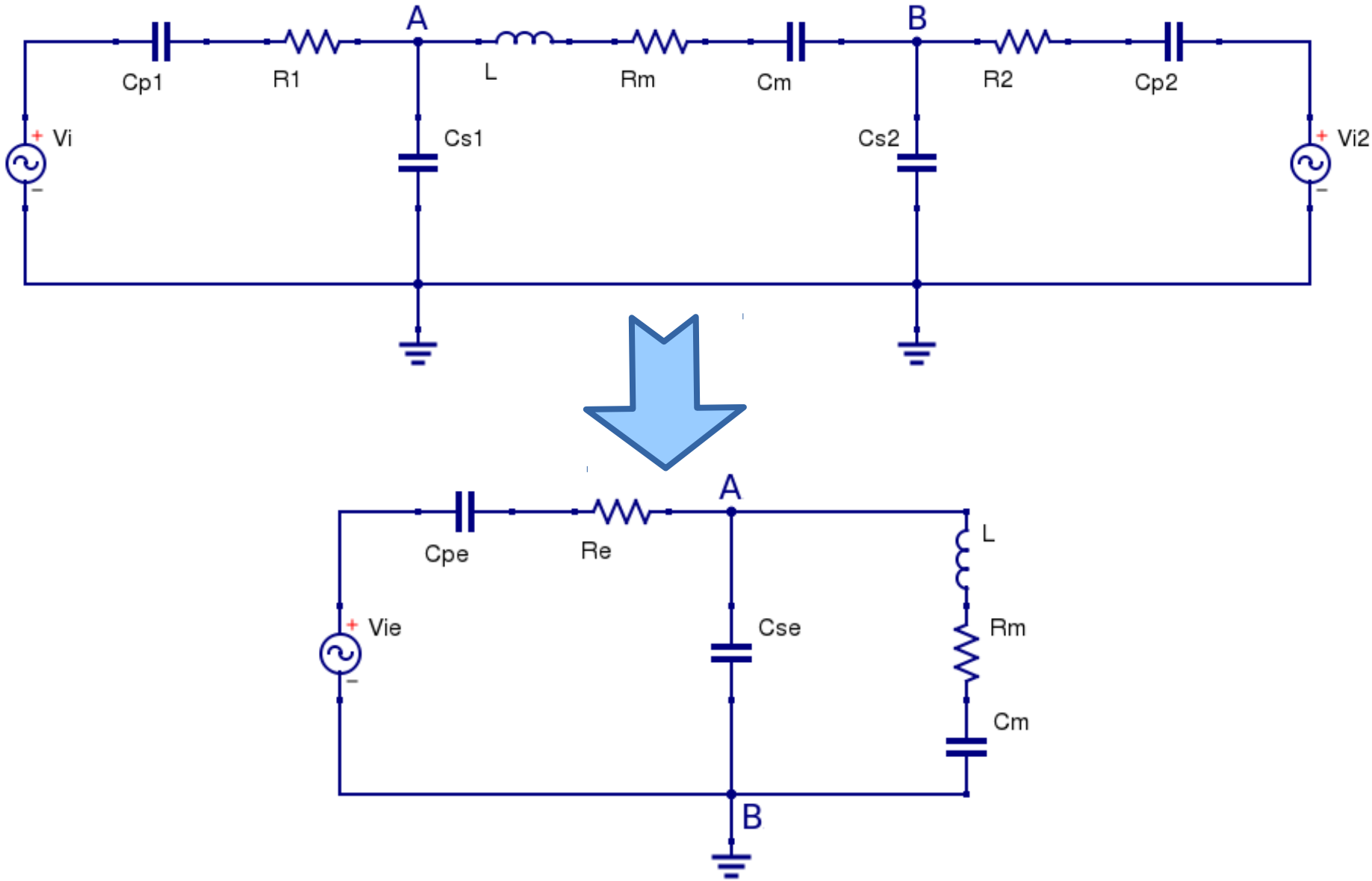
Hill model

- Hill model is the simplest model to capture tendon dynamics.
- It is however underdamped when using physiologically plausible parameters.

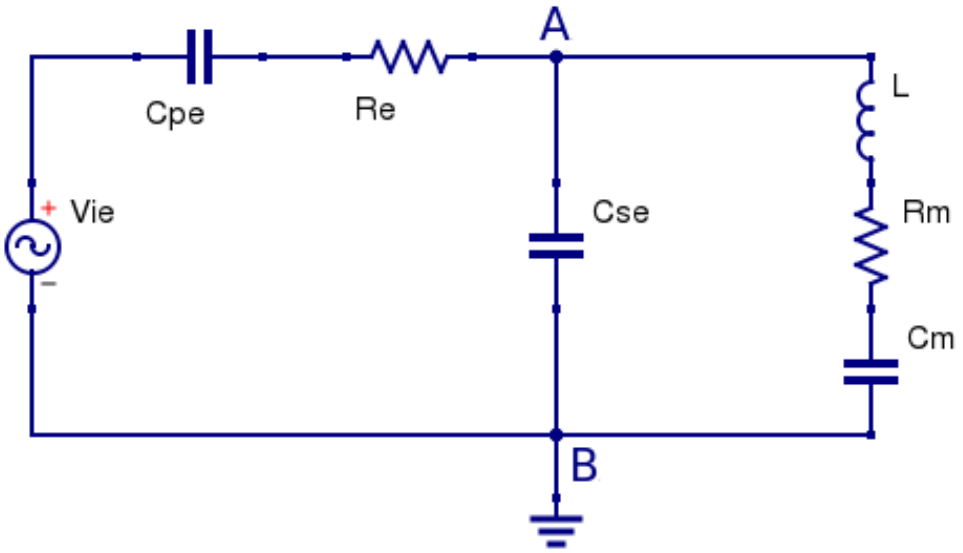
A2P2 model


PE
k_p
PD
c_p
F_1
CC
SE
k_s
Hill's muscle model
L
m
SE
k_s
Hill's muscle model
ME
k_m
MD
c_m
PE
k_p
PD
c_p
F_2
CC

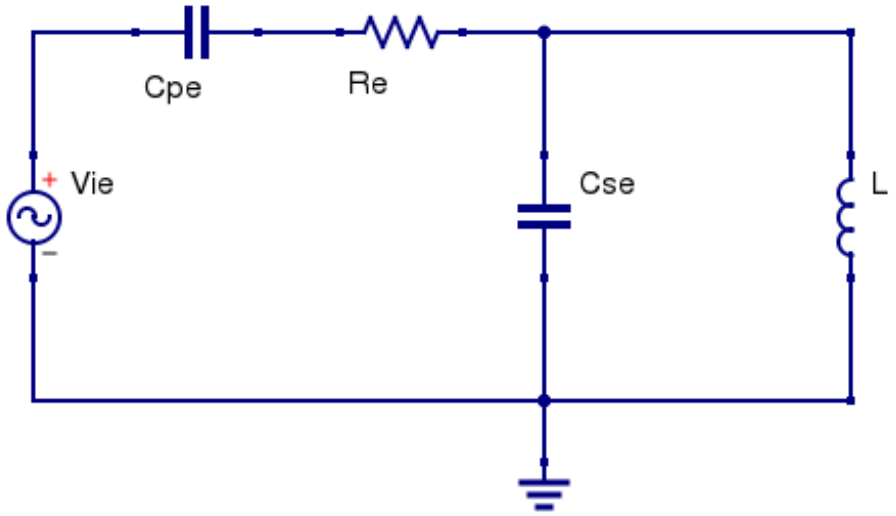
A2P2 model



A2P2 model



Hill model



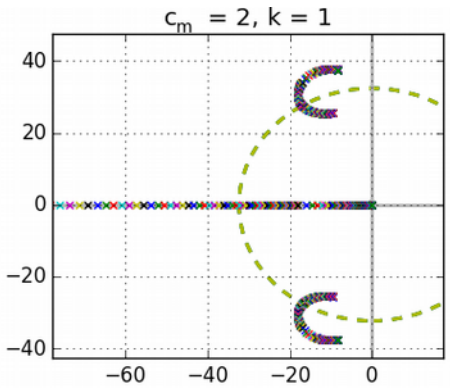
A2P2 model

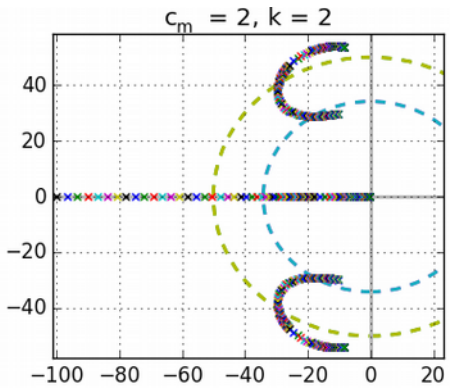
$$y_o(s) = \frac{1}{\frac{c_p m}{k_s} s^3 + \frac{(c_m c_p + m(k_p + k_s)}{k_s} s^2 + \frac{c_m(k_p + k_s) + c_p(k_m + k_s)}{k_s} s + \frac{k_m k_p}{k_s} + k_m + k_p}$$

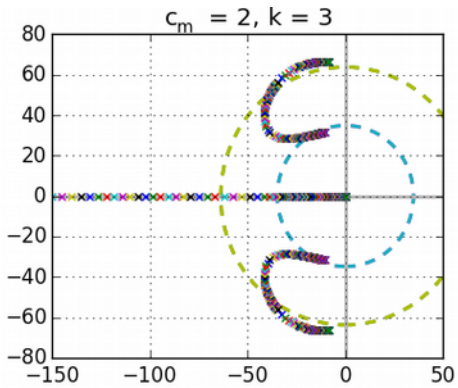
$$\omega_0 = \sqrt{\frac{k_p k_s}{m(k_p + k_s)}}$$

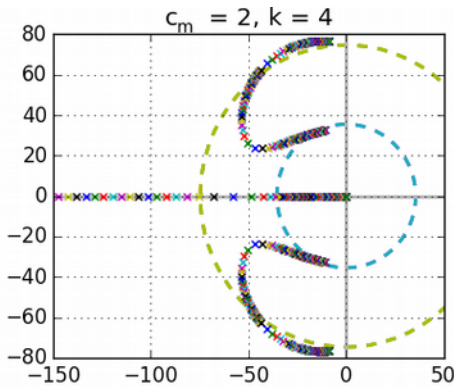
$$\omega_1 = \sqrt{\frac{k_p k_s + k_s^2}{m(k_p + k_s)}}$$

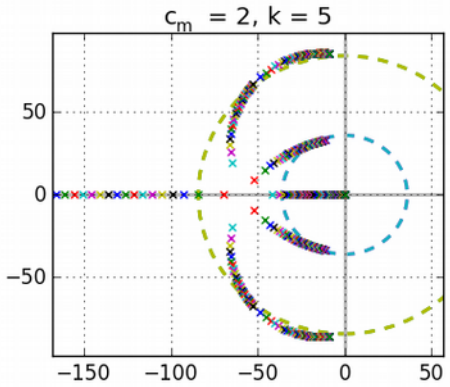
A2P2 model

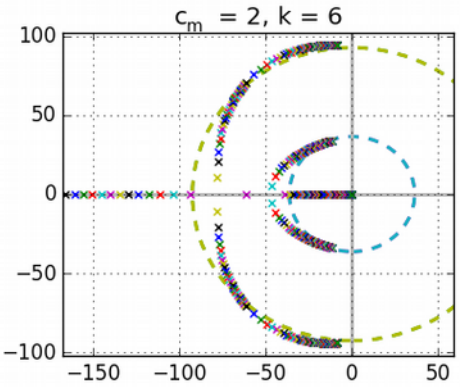

c_m = 2, k = 1

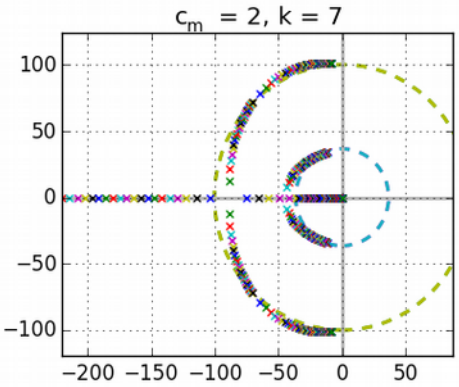

c_m = 2, k = 2

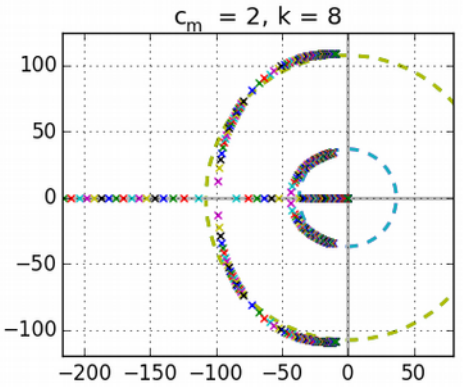

c_m = 2, k = 3

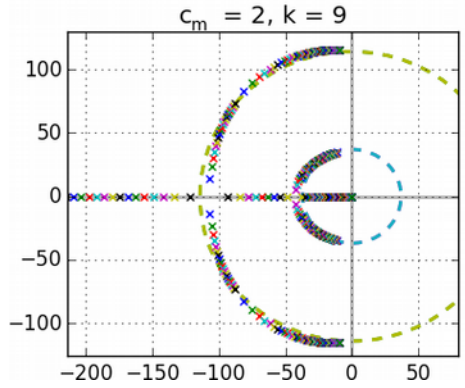

c_m = 2, k = 4

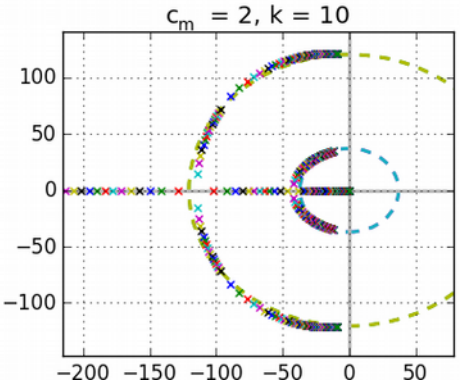

c_m = 2, k = 5

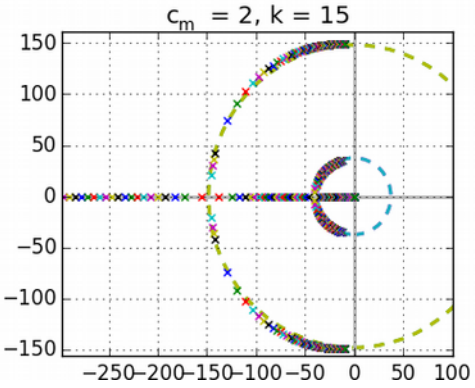

c_m = 2, k = 6

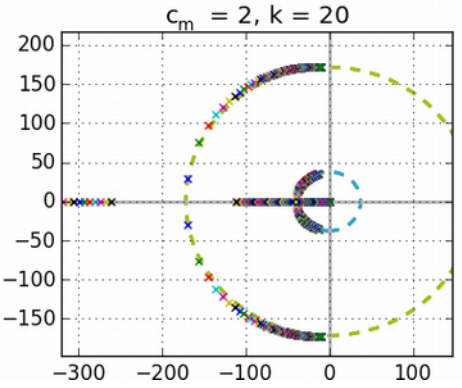

c_m = 2, k = 7


c_m = 2, k = 8

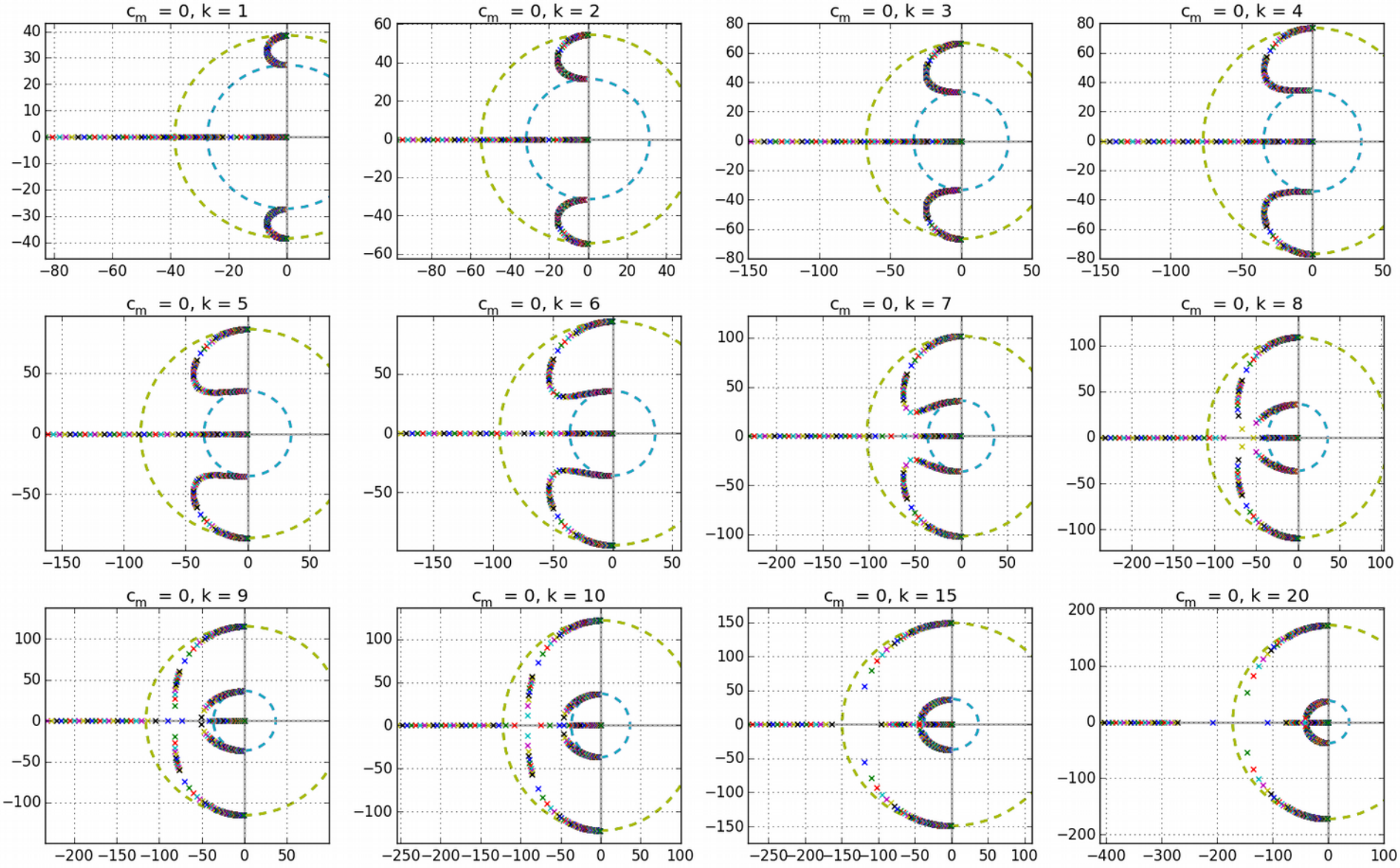

c_m = 2, k = 9


c_m = 2, k = 10

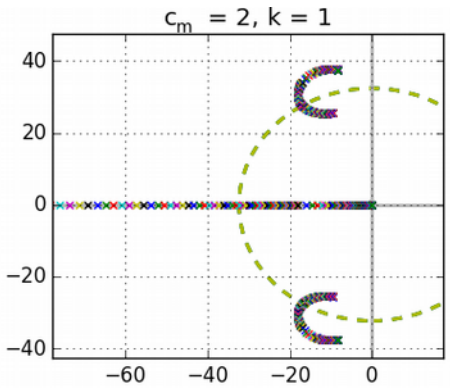

c_m = 2, k = 15

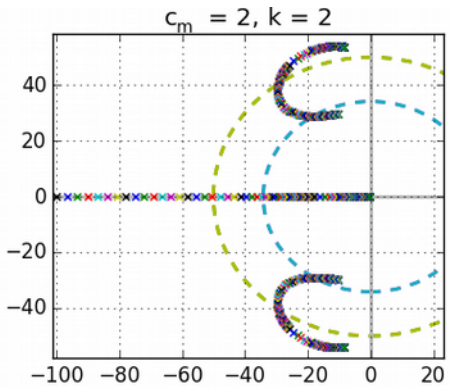

c_m = 2, k = 20

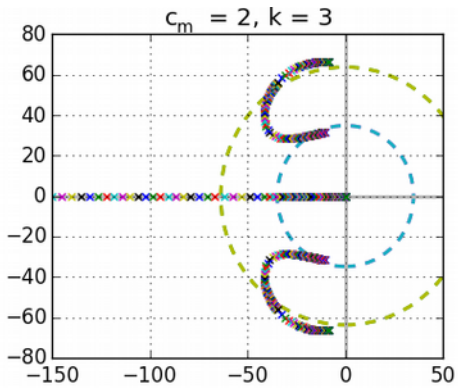
Hill type muscle model

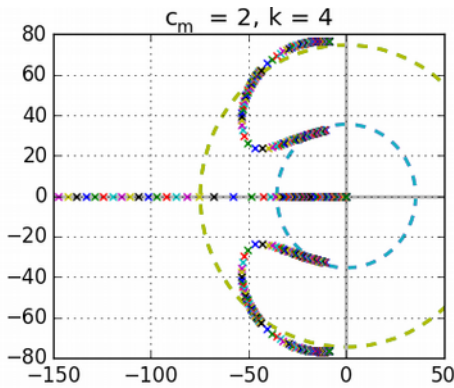


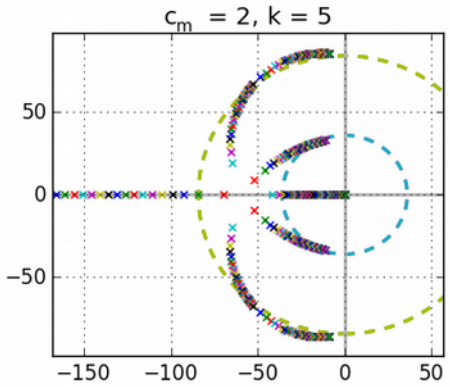
A2P2 model

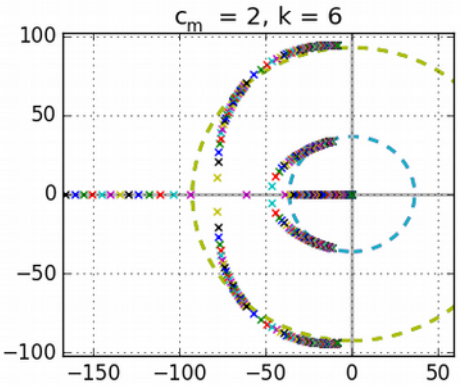

c_m = 2, k = 1

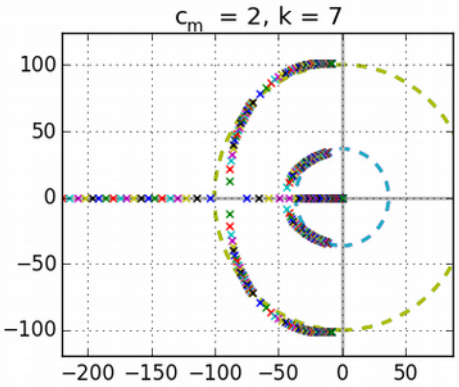

c_m = 2, k = 2

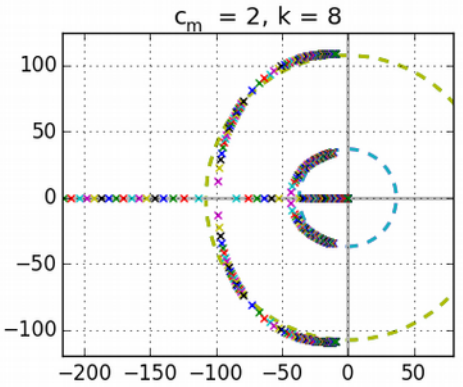

c_m = 2, k = 3

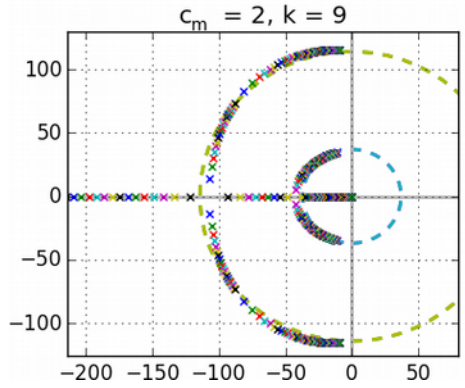

c_m = 2, k = 4

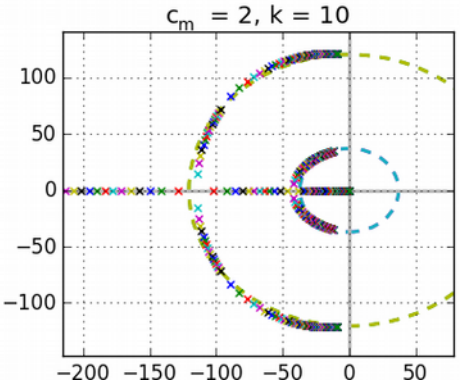

c_m = 2, k = 5

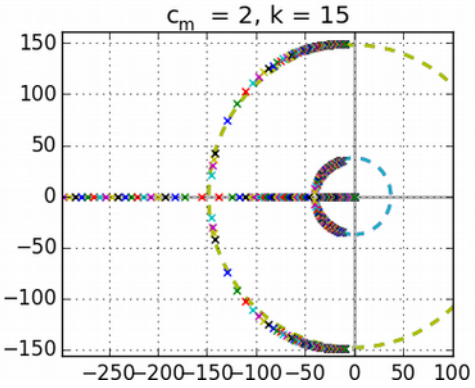

c_m = 2, k = 6

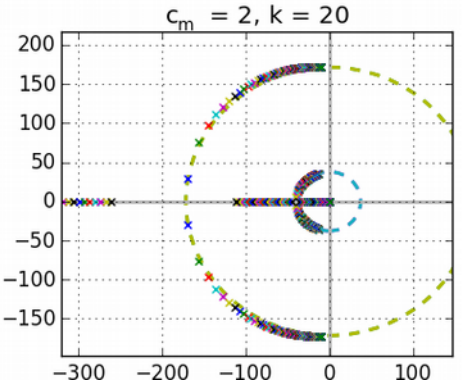

c_m = 2, k = 7


c_m = 2, k = 8

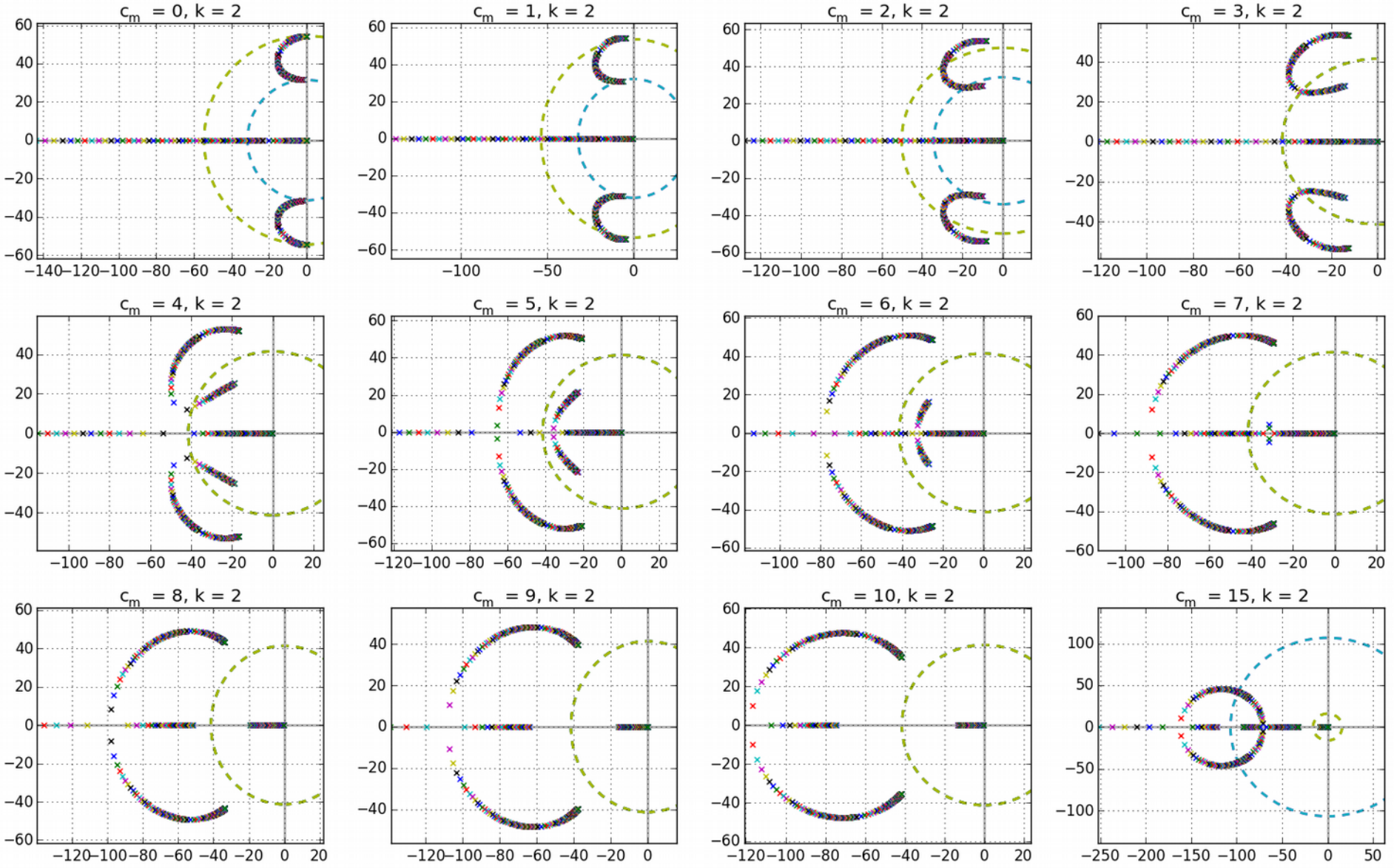

c_m = 2, k = 9


c_m = 2, k = 10


c_m = 2, k = 15


c_m = 2, k = 20

A2P2 model


c_m = 0, k = 2
c_m = 1, k = 2
c_m = 2, k = 2
c_m = 3, k = 2
c_m = 4, k = 2
c_m = 5, k = 2
c_m = 6, k = 2
c_m = 7, k = 2
c_m = 8, k = 2
c_m = 9, k = 2
c_m = 10, k = 2
c_m = 15, k = 2

Conclusion

- We propose an agonist-antagonist pitch production (A2P2) model to capture the opposing muscle physiological environment of pitch production.
- A simplified version of the model exhibits critical damping already for $k = 5$, for a thyro-cricoid joint damping of $c_m = 2$.
- For higher thyro-cricoid damping the model's damping range is even further increased.
- The model grants physiological plausibility to the use of critically damped, higher order system models in intonation modelling.

Acknowledgement

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  “SP2 - SCOPES Project on Speech Prosody”

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