

Appendix D

Bio inspired control rules for the leg sagittal DOFs

The control rules presented in this appendix are the ones from [8] (sometimes slightly modified). The different equations and explanations are adapted from [19] to match the ones used in this project.

Stance

- (1) $S_{SOL} = S_{MIN} + G_{SOL} \cdot \frac{F_{SOL}(t_l)}{F_{SOL}^{max}}$
 $F+$ generates compliant behavior
- (2) $S_{TA} = S_{MIN} + G_{TA,ST} \cdot (l_{CE,TA}(t_l) - l_{TA,ST}^{off} \cdot l_{opt,TA})$
- (3) $S_{GAS} = S_{MIN} + G_{GAS} \cdot \frac{F_{GAS}(t_l)}{F_{GAS}^{max}}$
 $F+$ prevents knee overextension + compliant leg behavior
- (4) $S_{VAS} = S_{0,VAS} + [G_{VAS} \cdot \frac{F_{VAS}(t_m)}{F_{VAS}^{max}}]_{\{\varphi_k\}}$
 $F+$ generates compliant behavior
- (5) $S_{HAM} = S_{MIN} + [k_p \cdot (\theta(t_s) - \theta_{ref}) + k_d \cdot \dot{\theta}(t_s)]_{\{+\}} \cdot k_{bw} \cdot \frac{|F_{leg}^{ipsi}(t_s)|}{F_g}$
 $\theta+$ is used to balance the trunk
- (6) $S_{GLU} = [S_{MIN} + [0.68 \cdot k_p \cdot (\theta(t_s) - \theta_{ref}) + k_d \cdot \dot{\theta}(t_s)]_{\{+\}} \cdot k_{bw} \cdot \frac{|F_{leg}^{ipsi}(t_s)|}{F_g}]_{\{SSup\}} - [S_{MIN}]_{\{DSup\}}$
 $\theta+$ is used to balance the trunk
 $\Delta S-$ further initiates swing in double support
- (7) $S_{HFL} = [S_{MIN} - [k_p \cdot (\theta(t_s) - \theta_{ref}) + k_d \cdot \dot{\theta}(t_s)]_{\{-}} \cdot k_{bw} \cdot \frac{|F_{leg}^{ipsi}(t_s)|}{F_g}]_{\{SSup\}} + [S_{MAX}]_{\{DSup\}}$
 $\theta - (< 0)$ is used to balance the trunk
 $\Delta S+$ further initiates swing in double support

Swing

- (1) $S_{SOL} = S_{MIN}$
silent: leg's ballistic motion
- (2) $S_{TA} = S_{MIN} + G_{TA,SW} \cdot (l_{CE,TA}(t_l) - l_{TA,SW}^{off} \cdot l_{opt,TA})$
 $L+$ prevents the ankle from overextending + foot clearance with the ground
- (3) $S_{GAS} = S_{MIN}$
silent: leg's ballistic motion
- (4) $S_{VAS} = S_{0,VAS}$
silent: leg's ballistic motion
- (5) $S_{HAM} = S_{MIN} + G_{HAM} \cdot \frac{F_{HAM}(t_s)}{F_{HAM}^{max}}$
 $F+$ transfers part of the protraction momentum into leg lowering and retraction
- (6) $S_{GLU} = S_{MIN} + G_{GLU} \cdot \frac{F_{GLU}(t_s)}{F_{GLU}^{max}}$
 $F+$ transfers part of the protraction momentum into leg lowering and retraction
- (7) $S_{HFL} = S_{MIN} + G_{HFL} \cdot (l_{CE,HFL}(t_s) - l_{HFL}^{off} \cdot l_{opt,HFL})$
 $- G_{HAM-HFL} \cdot (l_{CE,HAM}(t_s) - l_{HAM}^{off} \cdot l_{opt,HAM})$
 $L_{HFL}+$ modulates ballistic motion: facilitating leg protraction during swing
 $L_{HAM}-$ enforces swing-leg retraction, compensates for the hip rotation

S_{MIN} is the minimal stimulation and is equal to 0.01. S_{MAX} is the maximal stimulation and is equal to 1. Some terms are only added in special circumstances:

- $[]_{DSup}$: $\neq 0$ if trailing leg is in double support (finishing stance)
- $[]_{SSup}$: $\neq 0$ if trailing leg is in single support
- $[]_{\{+/-\}}$: $\neq 0$ if positive/negative values in $[]$
- $[]_{\{\varphi_k\}}$: $\neq 0$ if $\varphi_{knee} > \varphi_{knee}^{off}$ & $\varphi_{knee} > 0$