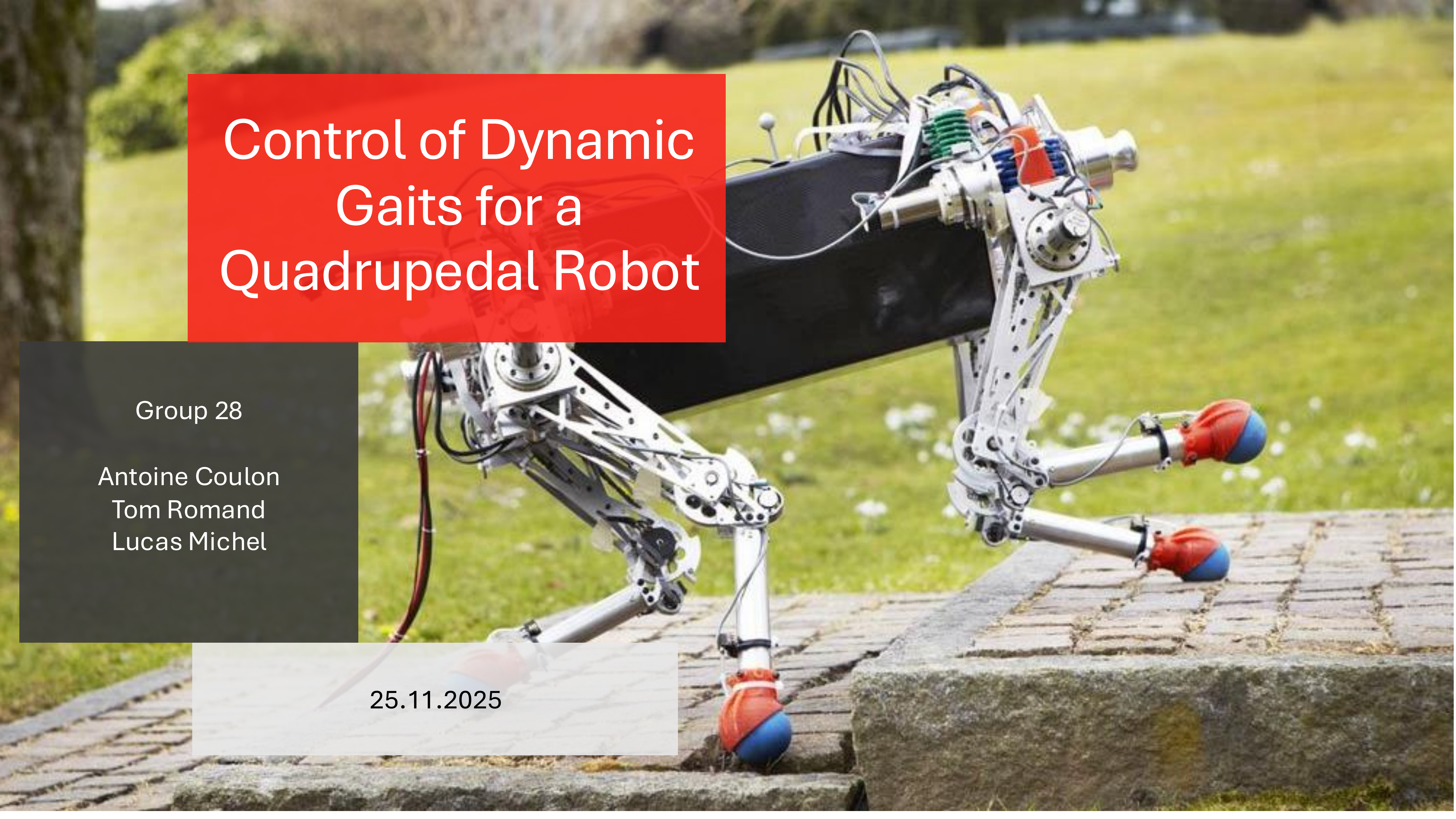

Control of Dynamic Gaits for a Quadrupedal Robot

Group 28

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Tom Romand
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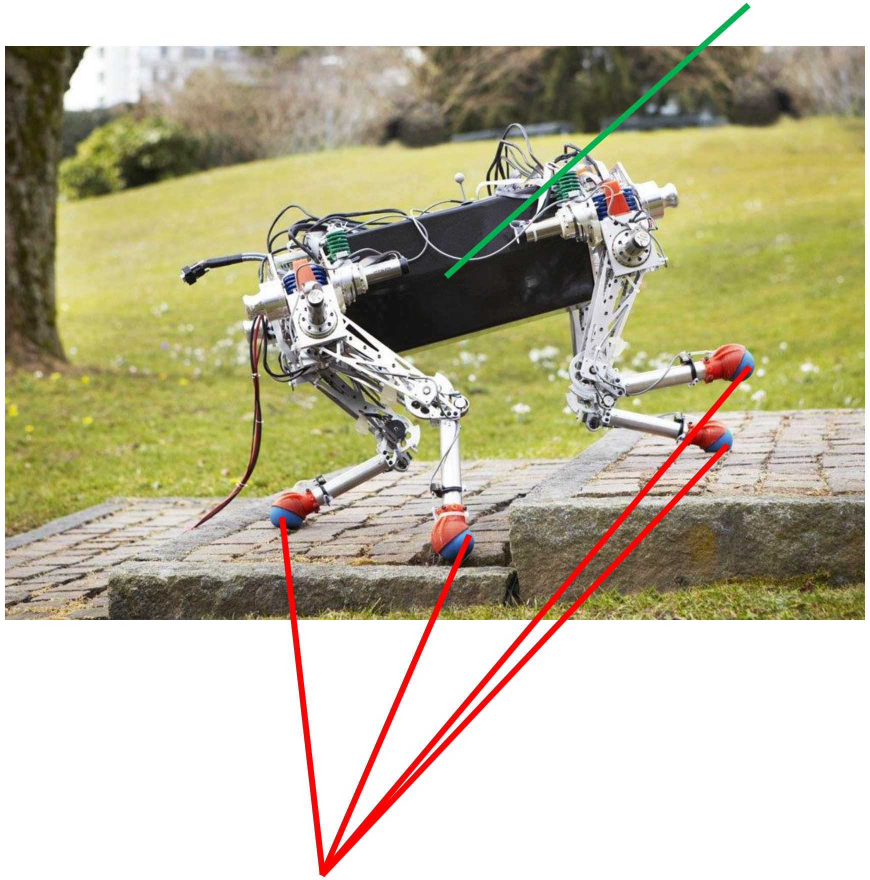
25.11.2025

The Plant

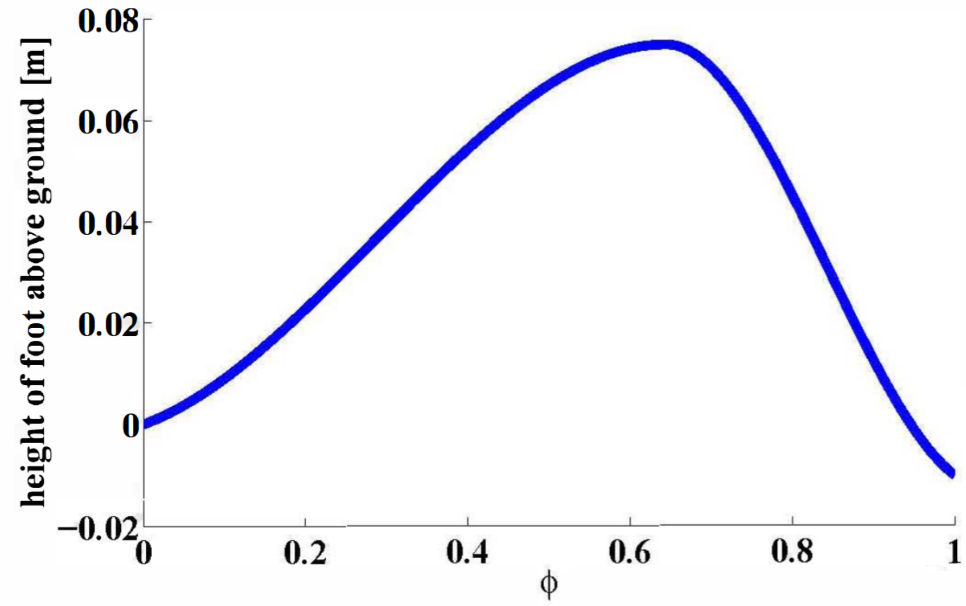
23 kg



Pressure sensors

- Electrically driven
- Series-elastic
- 12 DOF

Motion Generation

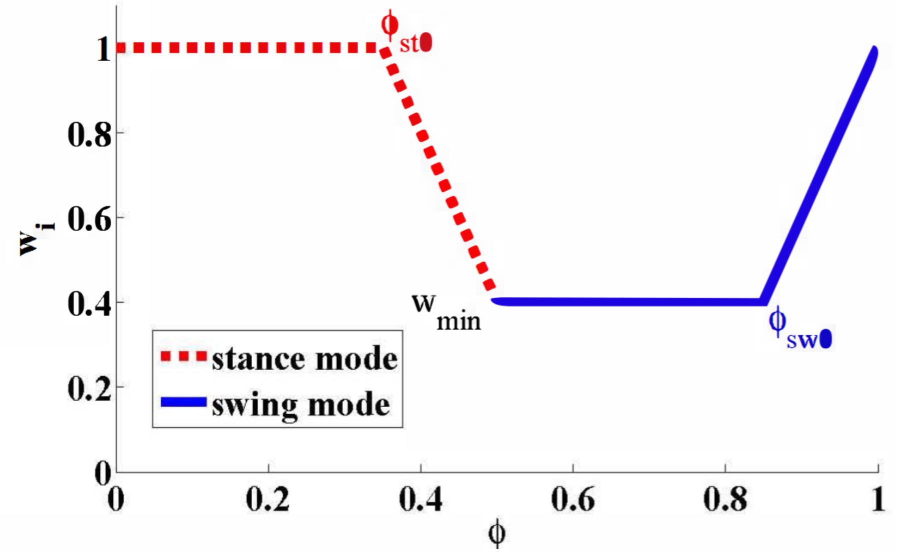


(a) Swing foot trajectory

$$h_g(t) = \sum_{i=0}^{N=4} c_{\text{flag}\,i}\left({}_I r_{\mathrm{F_i,z}} \cdot \alpha + h_g(t - \Delta t) \cdot (1 - \alpha)\right)$$

(b) Estimation of body height

Motion Generation

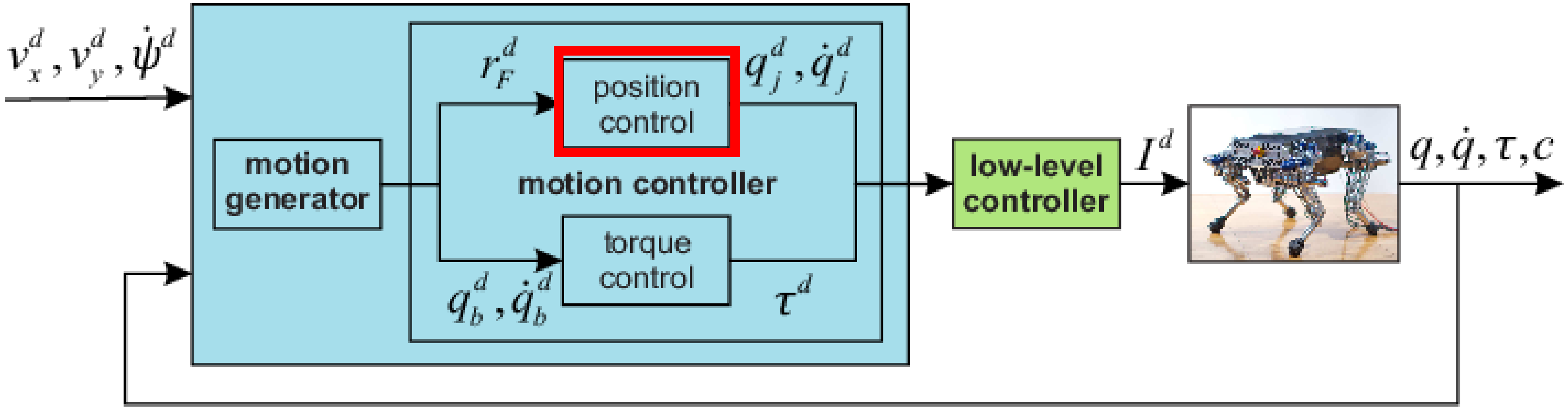


(c) Weights for balance control depending on stride phase

$$ {}_{I}\boldsymbol{r}_{\mathrm{B}}^{d} = \frac{\sum_{i=1}^{N} w_i(\phi)\, {}_{I}\boldsymbol{r}_{\mathrm{F_i}}}{\sum_{i=1}^{N} w_i(\phi)} $$

(d) Desired body position

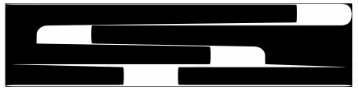
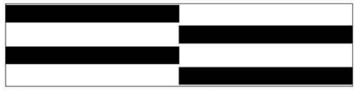
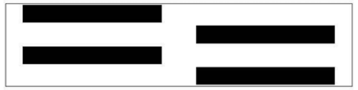
Motion Control



- Position controller for swing legs
- Torque controller for stance legs

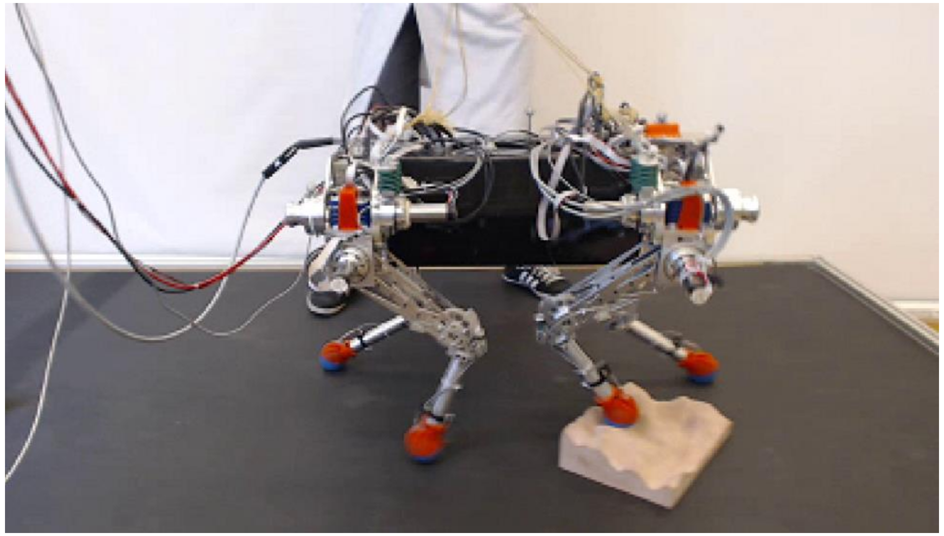
Results : Parameter Sets

TABLE I
PARAMETER SETS FOR DIFFERENT GAITS

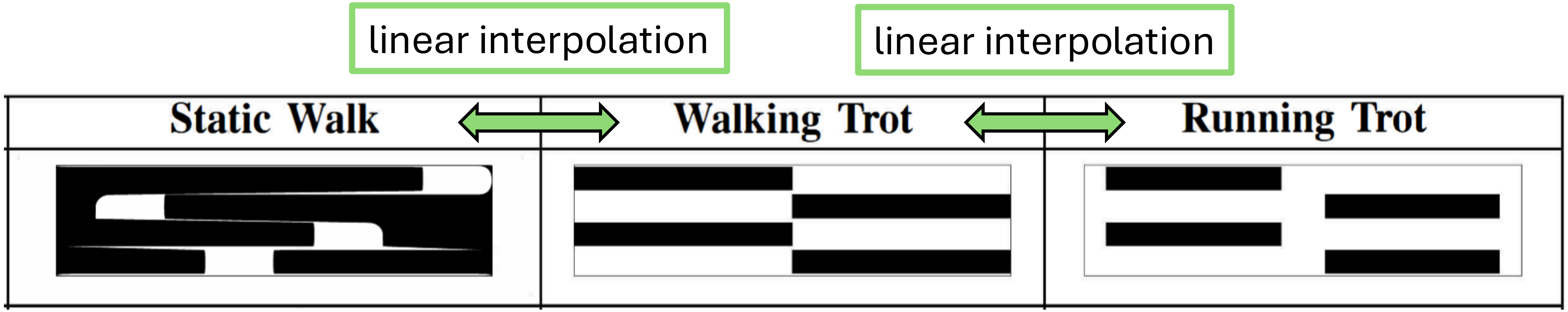
Parameter	Symbol	Static Walk	Walking Trot	Running Trot
gait graph				
stride duration	$T_s[s]$	1.5	0.8	0.7
min. leg weight for support polygon	w_{min}	0.35	0.15	0.15
start of increasing the weight of a swing leg for support polygon	$\phi_{\mathrm{sw},0}$	0.7	0.7	0.7
start of decreasing the weight of the stance leg for support polygon	$\phi_{\mathrm{st},0}$	0.7	0.7	0.7
default left front swing leg offset	${}_B\boldsymbol{r}^d_{\mathrm{HF}}[m]$	$[0, -0.01, 0]^T$	$[0, 0, 0]^T$	$[0, 0, 0]^T$
default left hind swing leg offset	${}_B\boldsymbol{r}^d_{\mathrm{HF}}[m]$	$[0, 0.14, 0]^T$	$[0, 0, 0]^T$	$[0, 0, 0]^T$
height of middle of hip AA joints	$h_H[m]$	0.39	0.44	0.44
virt. force proportional gain	$\boldsymbol{k}_p$	$[500, 640, 600, 400, 200, 0]^T$	$[0, 640, 600, 400, 200, 0]^T$	$[0, 640, 2600, 400, 200, 0]^T$
virt. force derivative gain	$\boldsymbol{k}_d$	$[150, 100, 120, 6, 9, 0]^T$	$[150, 100, 120, 6, 9, 0]^T$	$[90, 60, 120, 6, 9, 0]^T$
virt. force feed-forward gain	$\boldsymbol{k}_{ff}$	$[25, 0, 1, 0, 0, 0]^T$	$[60, 0, 1, 0, 0, 0]^T$	$[25, 0, 1, 0, 0, 0]^T$
weights for matching the des. virt. forces	S	$\mathrm{diag}(1, 1, 1, 10, 10, 5)$	$\mathrm{diag}(1, 1, 0.2, 20, 20, 5)$	$\mathrm{diag}(1, 1, 0.2, 20, 20, 5)$
weights for reducing joint torques	W	$\mathrm{diag}(0.00001 \ldots)$	$\mathrm{diag}(0.00001 \ldots)$	$\mathrm{diag}(0.00001 \ldots)$

Results : Robustness

- Tests involved unperceived 5 cm obstacles and external pushes
- Recovery using foot placement and force distribution strategies
- Failures only occurred when joint limits were reached
- Force and torque data confirmed stable recovery behavior

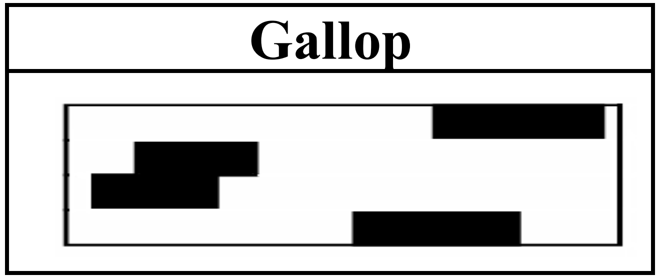


Results : Gait Transitions



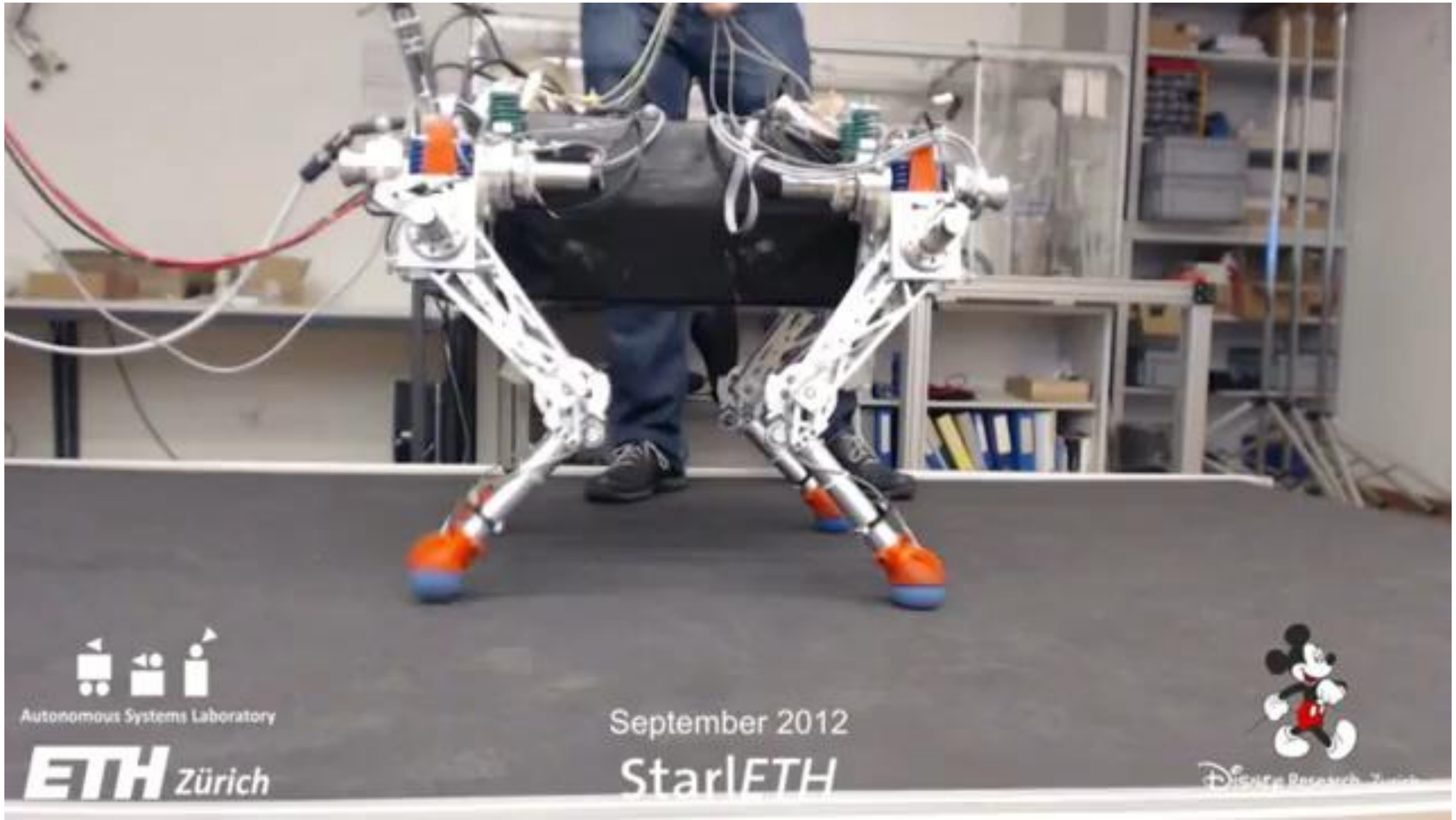
Transitions :

- Triggered manually by an external user
- Based on desired speed



Incompatible gait, no interpolation

Gait Transitions



Pros and Cons

Pros

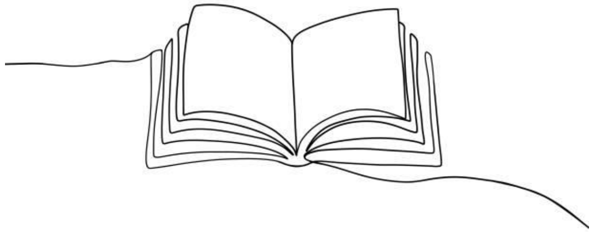
- Smooth transition easily implemented
- Modular and intuitive tuning
- Robustness

Cons

- Some gaits transition impossible

Citations

- Cited 263 times
- Used for quadrupedal control over complex environments
- Used for bio-inspired/smooth gaits transitions



Questions ?