PhD Meeting: Planning and Control

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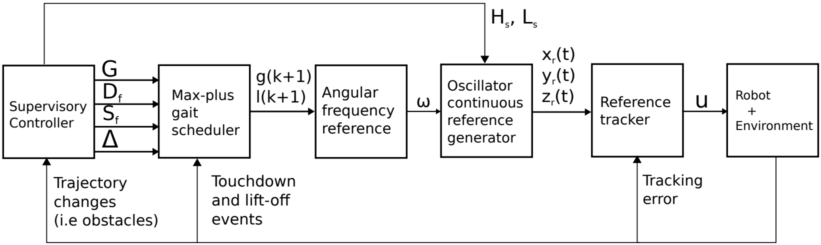
Outline

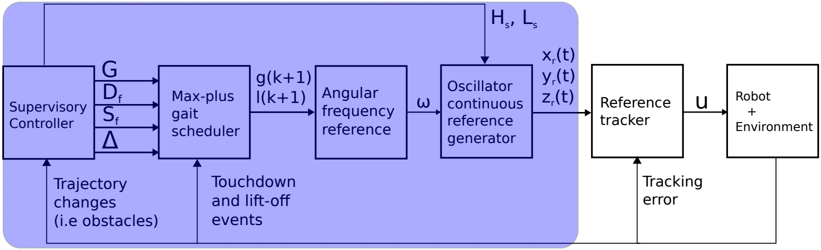
1. Control structure
2. Simulations
3. Further work

Outline

General picture



General picture



Supervisory controller

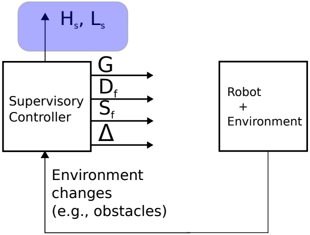
Main goal

Provide **time** and **geometrical** gait parameters, based on sensory data, to overcome the scenario that the robot is facing.

Supervisory controller (continue)

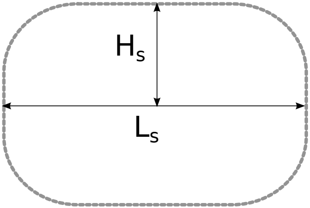
Geometrical parameters:

- Step height H_s



- Step length L_s

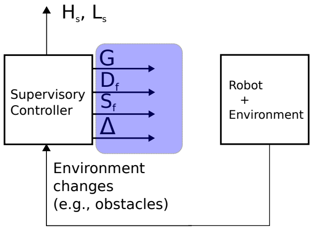
- Oscillator "primitive" shape changes

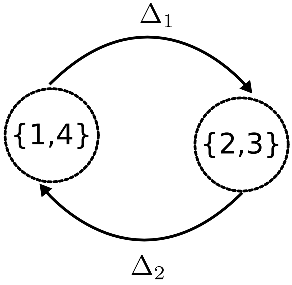


Supervisory controller (continue)

Time parameters:

- Duty factor D_f
- Step frequency S_f
- Gait "ordering" G (e.g., $G_{trot} = \{1, 4\} \prec \{2, 3\}$)
- Time difference vector Δ



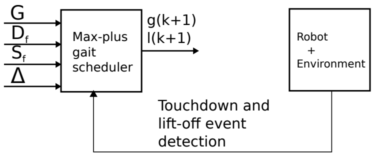


Max-plus gait scheduler

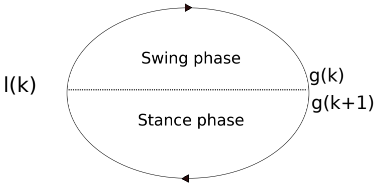
Main goal

Using the **time**-related gait parameters provided by the supervisory controller, generate the list of time-instants when each leg has to leave and touch the ground, so that a desired coordination is achieved.

Max-plus gait scheduler (continue)



$$G_{trot} = \{1,4\} \prec \{2,3\}$$
$$D_f = 0.5$$
$$S_f = 0.36$$
$$\Delta = [0.2, 0.2]$$



k	$t_1(k)$	$t_2(k)$	$t_3(k)$	$t_4(k)$	$l_1(k)$	$l_2(k)$	$l_3(k)$	$l_4(k)$
0	0	0	0	0	0	0	0	0
1	2.4	3.6	3.6	2.4	1.4	2.6	2.6	1.4
2	4.8	6.0	6.0	4.8	3.8	5.0	5.0	3.8
3	7.2	8.4	8.4	7.2	6.2	7.4	7.4	6.2
4	9.6	10.8	10.8	9.6	8.6	9.8	9.8	8.6
5	12.0	13.2	13.2	12.0	11.0	12.2	12.2	11.0

Max-plus gait scheduler (continue)

- Systematic gait generation
- No coupling matrix $\mathbb{C}_{ij}$
- Total cycle time analysis
- Coupling time analysis
- Not computationally expensive
- Possibility to provide "optimal" gait switching

Angular frequency reference generator

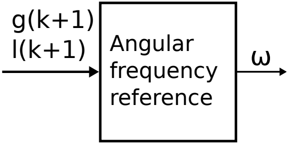
Main goal

Making use of the **touchdown** and **lift-off** times of the max-plus gait scheduler, provide a function for the evolution of the angular frequency of the oscillator-based reference generator.

Angular frequency reference generator (continue)

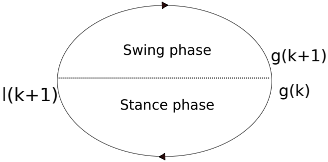
Stance and swing period:

$$
\begin{aligned}
Ti_{st} &= l_i(k+1) - g_i(k) \\
Ti_{sw} &= g_i(k+1) - l_i(k+1),
\end{aligned}
$$



Average angular frequency:

$$
\bar{\omega} = \begin{cases} \frac{\pi}{Ti_{st}} \ \textbf{for} \ t \in [g_i(k), l_i(k+1)] \\ \frac{\pi}{Ti_{sw}} \ \textbf{for} \ t \in (l_i(k+1), g_i(k+1)] \end{cases}
$$

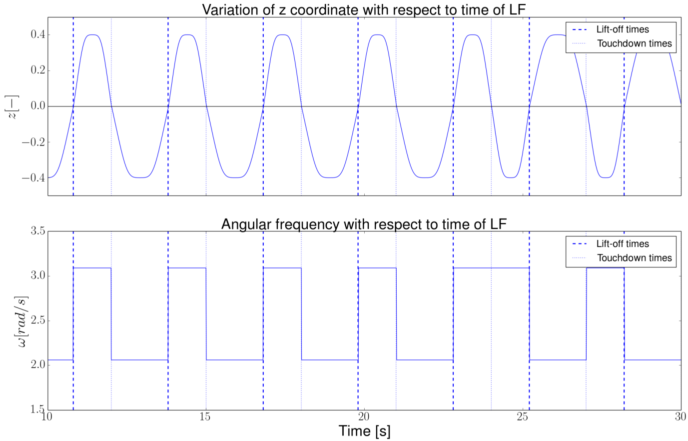


Condition for the angular frequency function:

$$
\frac{1}{Ti_p} \int^{Ti_p} \omega dt = \bar{\omega} \ \textbf{for} \ p = st, sw.
$$

Angular frequency reference generator (continue)

$$\omega = \bar{\omega}$$



Oscillator continuous time reference generator

Main goal

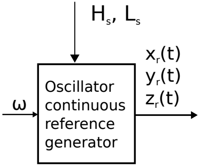
Generate reference trajectories for each of the legs of the robot in such a way that the desired gait is achieved, according to the angular frequency obtained from the angular frequency reference generator.

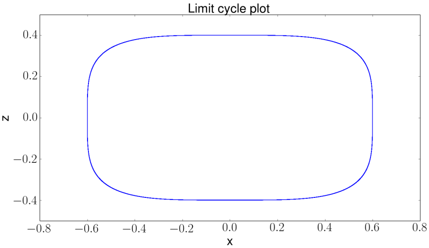
Oscillator continuous time reference generator (continue)

Oscillator equations:

$$x = \alpha(1 - \frac{16x^4}{L_s^4} - \frac{z^4}{H_s^4})x + \frac{1.18\omega L_s}{2H_s^3}z^3$$

$$z = \beta(1 - \frac{16x^4}{L_s^4} - \frac{z^4}{H_s^4})z - \frac{9.44\omega H_s}{L_s^3}x^3$$





Outline

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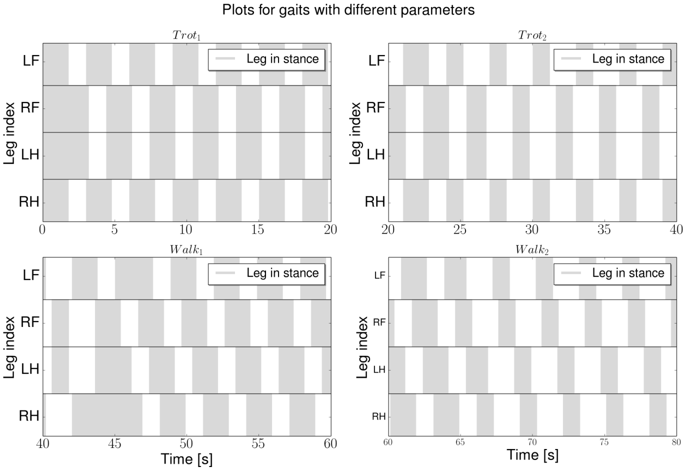
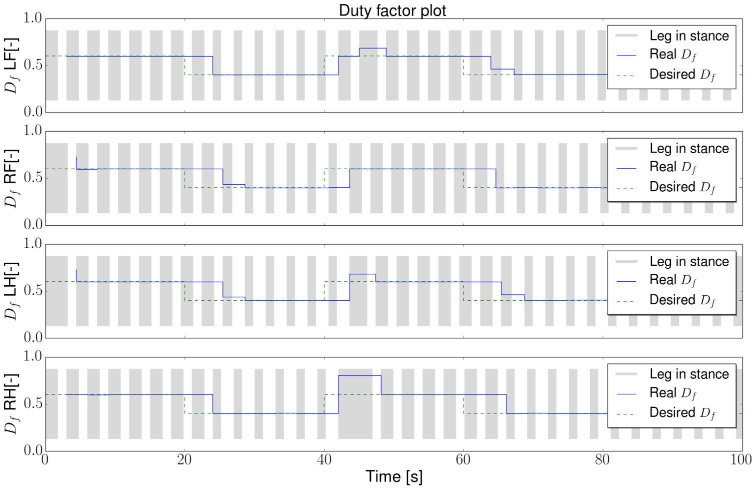
Parameters used

	G	D_f	$S_f[\frac{1}{s}]$	$\Delta[s]$
T_1	$\{1,4\} \prec \{2,3\}$	0.6	1/3	$[0.2, 0.4]$
T_2	$\{1,4\} \prec \{2,3\}$	0.4	1/3	$[-0.2, -0.4]$
W_1	$\{1\} \prec \{2\} \prec \{3\} \prec \{4\}$	0.6	1/3	$[-0.45, -0.45, -0.45, -0.45]$
W_2	$\{1\} \prec \{2\} \prec \{3\} \prec \{4\}$	0.4	1/3	$[-1.4, -0.7, -1.4, -0.7]$

Generated motion references



Duty factor



Duty factor plot
D_f LF[-]
D_f RF[-]
D_f LH[-]
D_f RH[-]
Leg in stance
Real D_f
Desired D_f
0.0
0.5
1.0
0
20
40
60
80
100
Time [s]

Outline

Further work

- Use the proposed strategy in the current framework
- Design angular frequency generator
- Account for disturbances in the max-plus algebra gait scheduler
- Design of supervisory parameters according to sensory information
- Design transition between one set of parameters to another

Thank you for your attention. Any questions?