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Optimization of Gaits with a Soft Contact Model

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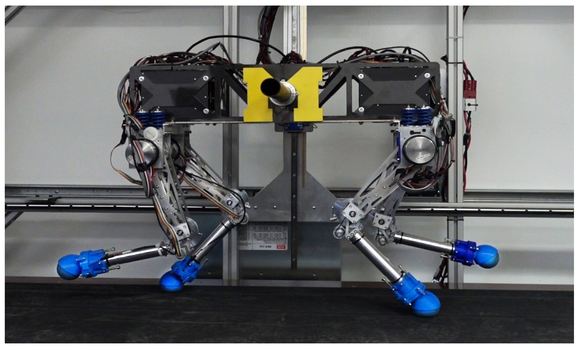
RAMlab
Robotics and Motion Laboratory

imprs-is

Motivation

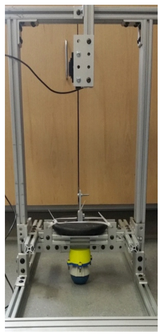
Observable foot-compliance during ground interaction



Are fully rigid contact models superior to soft contact models in gait optimization?

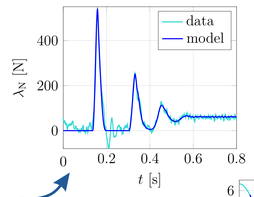
Soft Contact Model

series of foot-drops

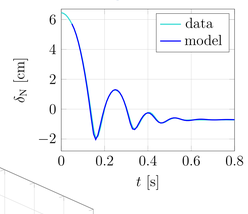


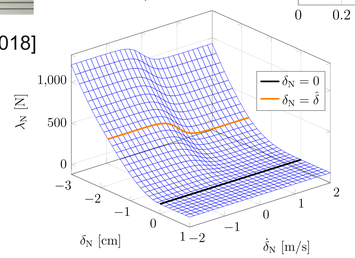
[Schumann 2018]

normal force



displacement





$$\lambda_N(\delta_N, \dot{\delta}_N) = \begin{cases} 0 & , \delta_N \geq 0 \\ f_s(\delta_N) + f_d(\dot{\delta}_N) s(\delta_N; \hat{\delta}) & , \hat{\delta} < \delta_N < 0 \\ f_s(\delta_N) + f_d(\dot{\delta}_N) & , \delta_N \leq \hat{\delta}, \end{cases}$$

Model Properties

Soft contact model

- C^1 -continuous in $\delta_N, \dot{\delta}_N$
- smoothing coefficient $\hat{\delta}$
- no sticking forces: $\lambda_N \geq 0 \quad \forall \delta_N, \dot{\delta}_N$

Hard contact model

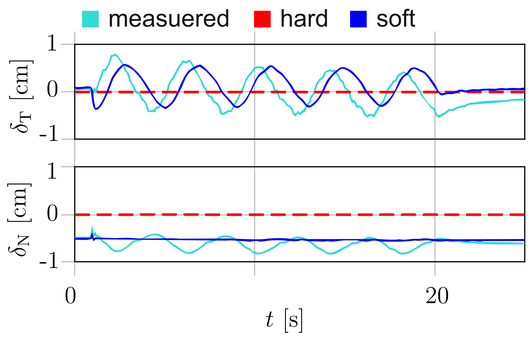
rigid body (hybrid dynamics):

- no foot deformation $\delta_N \geq 0, \ \delta_T = 0$
- holonomic non-slipping constraint in stance

Model Verification

Simulation results of RAMbi (squatting)

- deformations (δ_T, δ_N) of a single foot



Transcription

Direct collocation

- Hermite-Simpson splines
  (similar to Frost [Ayonga 2017])

Implementation

- multi-phase (hard contact model)
- exploits sparse structure, analytic gradients
- mesh refinement

Gait Optimization

Both contact models were implemented for a monopedal robot

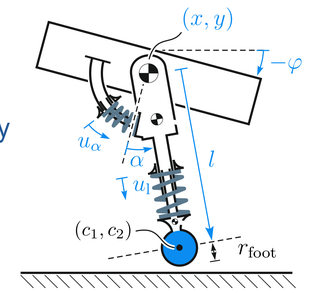
- fixed horizontal speed in periodicity constraints

Objective function:

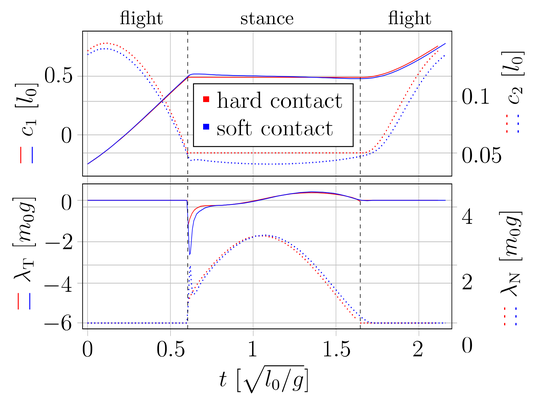
- thermal losses in motors

Initial guess:

- upright standing trajectory



7 DoF monoped



Conclusion

The soft contact model is showing substantial compliance

- resembles experiments much closer than the rigid contact model

Contact models in gait optimization:

soft contact model	hard contact model
- contact invariant (single-phase optimization)	- about twice as fast - requires fewer mesh points

A good initial guess is essential for both contact models

References

Remy, C. David, Keith Buffinton, and Roland Siegwart. "Comparison of cost functions for electrically driven running robots." 2012 IEEE International Conference on Robotics and Automation. IEEE, 2012.

Hereid, Ayonga, and Aaron D. Ames. "FROST*: Fast robot optimization and simulation toolkit." 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2017.

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