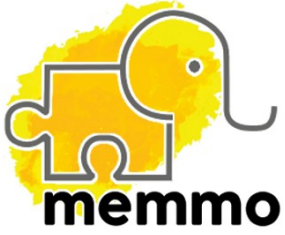
Quadrupedal Motion Planning for ~~Legged~~ Robots

– Robots & Methods –

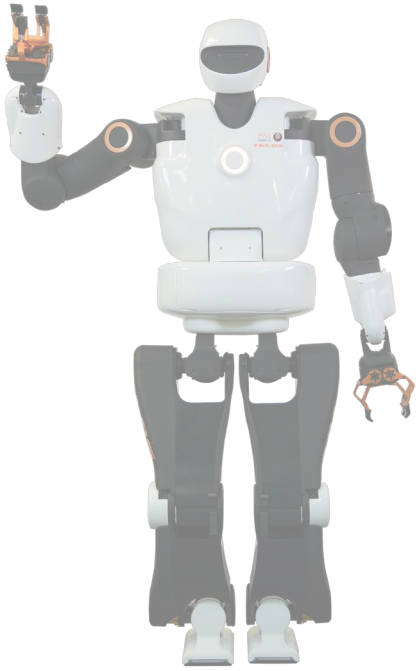


Ioannis Havoutis & Mathieu Geisert

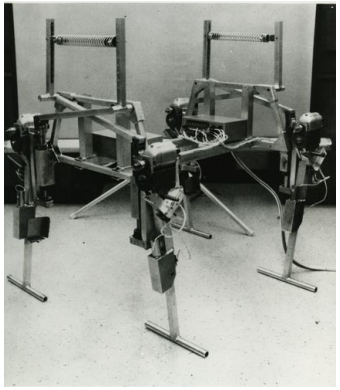
Legged Robots of MEMMO

ORI autonomous systems

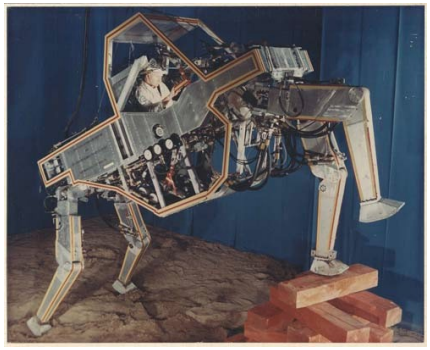
UNIVERSITY OF OXFORD



Early days

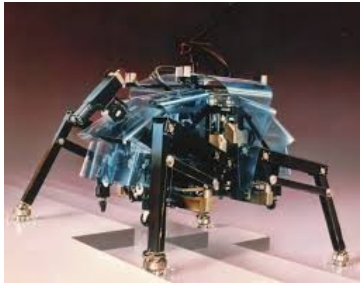


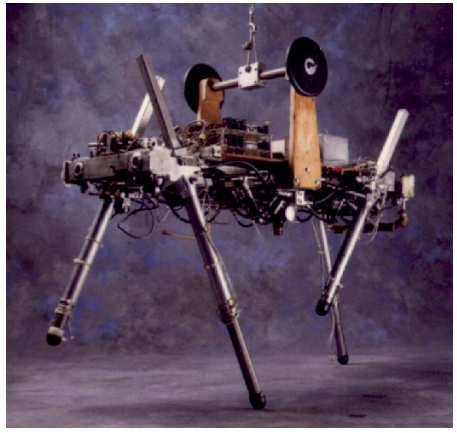
Phony Pony, Frank & McGhee



Walking Truck GM

Hirose Lab Titan

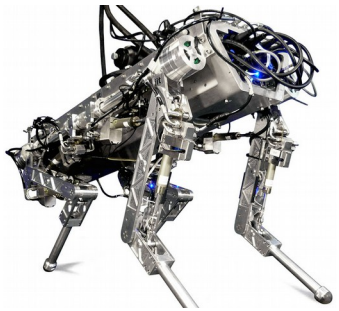


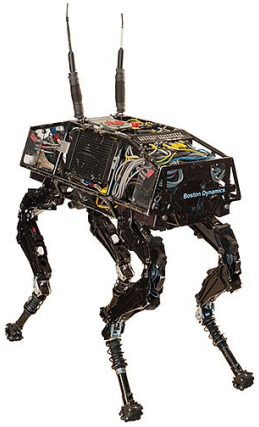


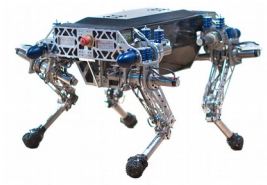
MIT Quadruped Raibert

1968 1978 1985 1984 1987

Recent years

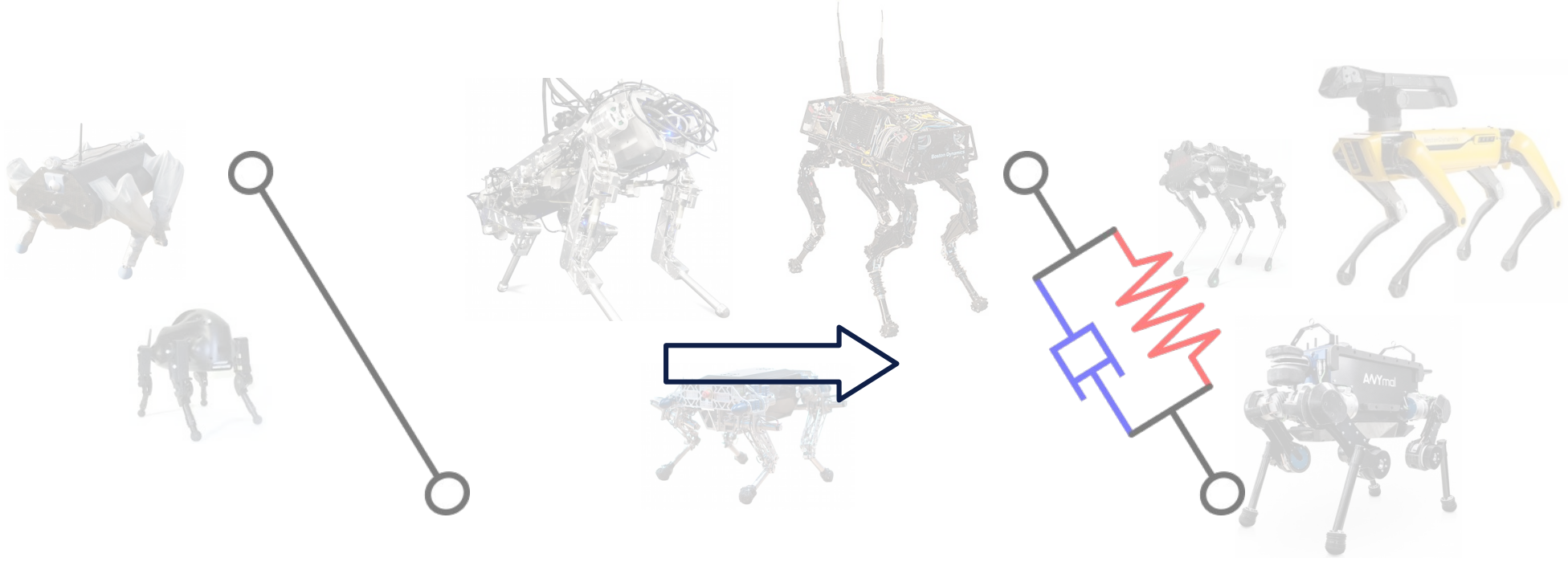


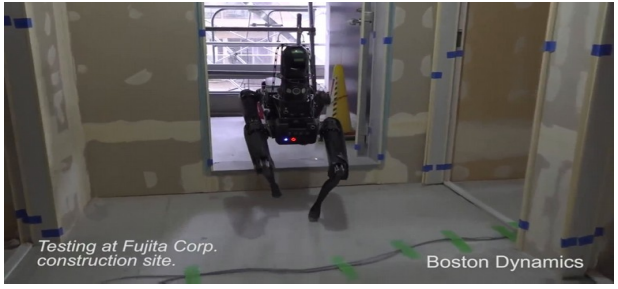




2005 2010 2016 2019

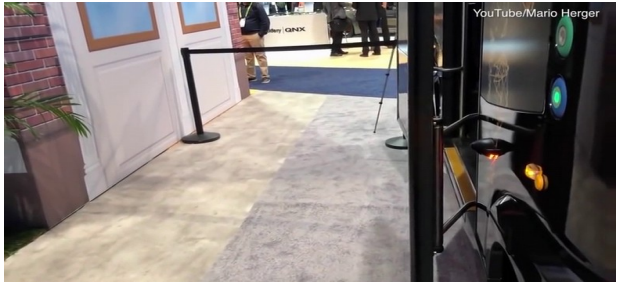
Recent years



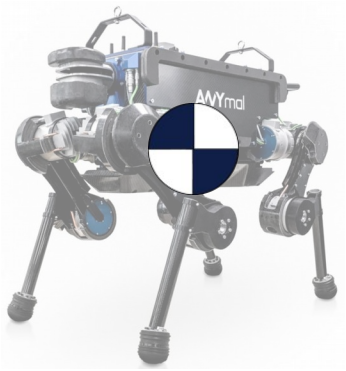

Testing at Fujita Corp.
construction site.
Boston Dynamics


ANYmal
North Sea
September 2018
ANYbotics

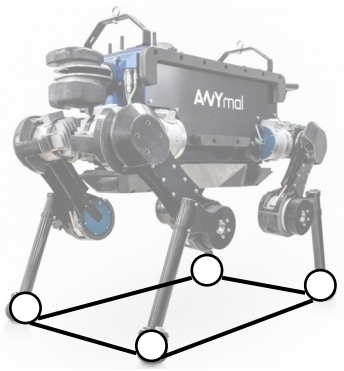

段差よし
Robot testing at Takenaka
Corp. construction site.
Boston Dynamics


YouTube/Mario Herger

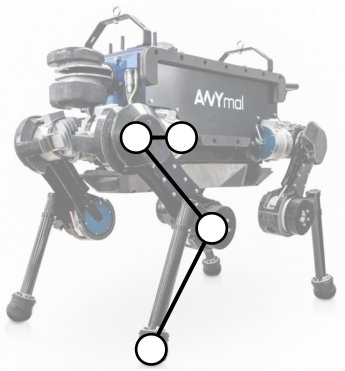
Advantages



CoM

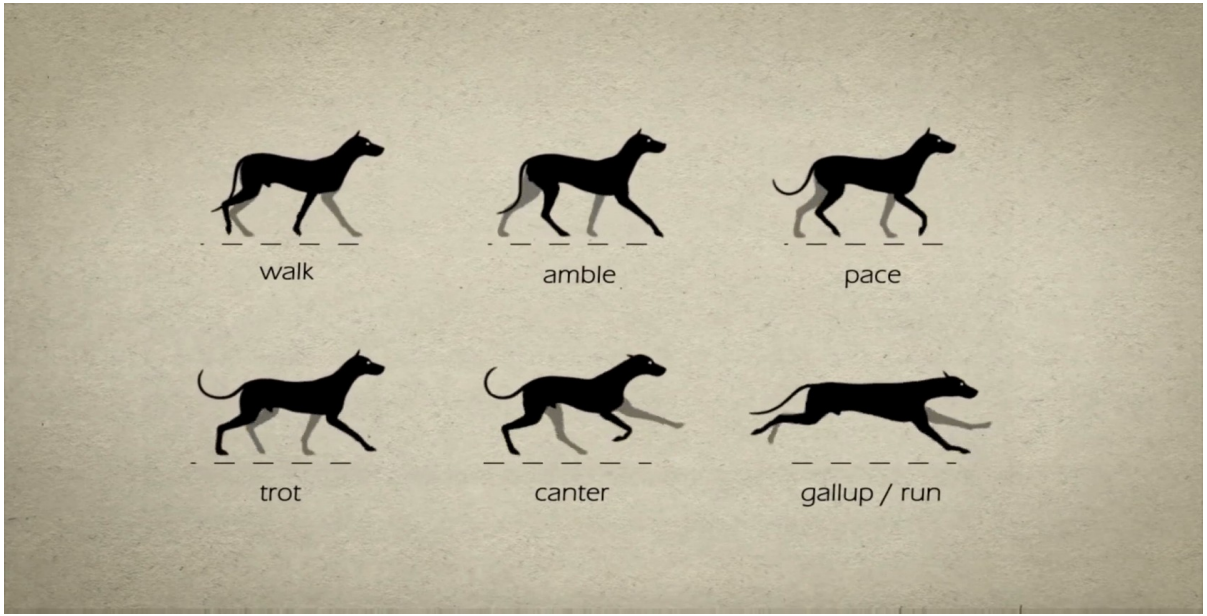


Area of Support



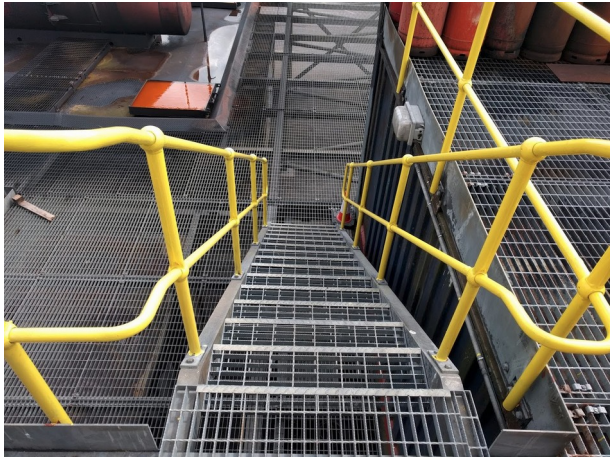
Simple Leg Kinematics

Gaits

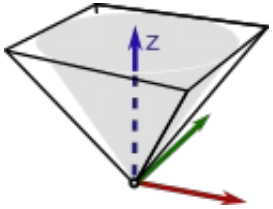


[source: Animal Gaits for Animators, Stephen Cunnane (https://vimeo.com/215637283)]

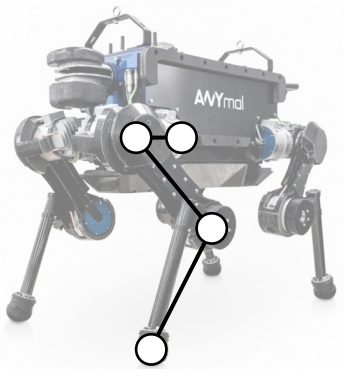
Examples



Complexity

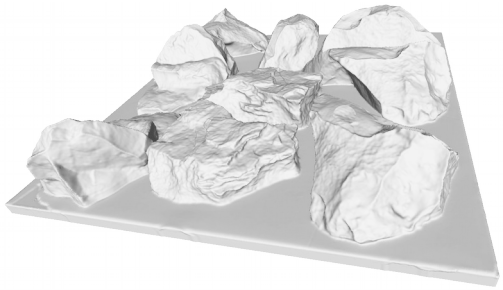


Contacts



Constraints

+



~

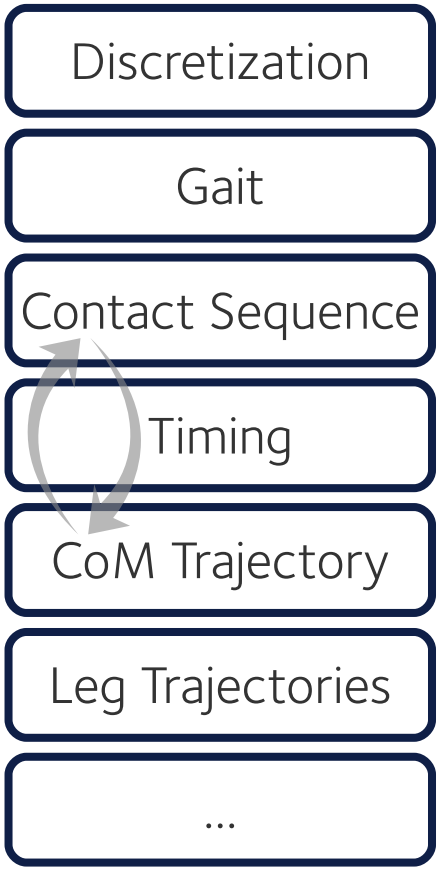
System

Environment

...

Taxonomy

Search/Sampling



Engineering Approach

+ Set of small problems
+ Good solutions
+ Fast

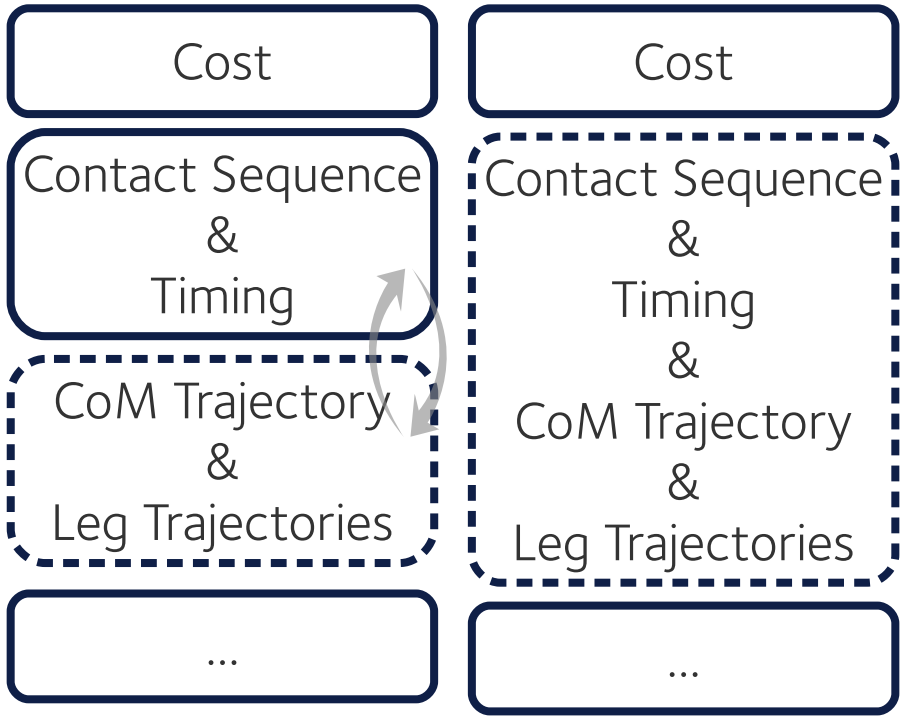
– Limited performance as blocks often coupled
– Heuristics
– Hand-tuning

Taxonomy

Search/Sampling

- Discretization
- Gait
- Contact Sequence
- Timing
- CoM Trajectory
- Leg Trajectories
- ...

Optimization



Informatics Approach

+ Better approximation of the perf. envelope
+ Flexible

- Many design decisions
- Local optima/minima
- Computational cost
- Cost tuning

Taxonomy

ORI autonomous systems

UNIVERSITY OF OXFORD

Search/Sampling

- Discretization
- Gait
- Contact Sequence
- Timing
- CoM Trajectory
- Leg Trajectories
- ...

Optimization

- Cost
- Contact Sequence & Timing
- CoM Trajectory & Leg Trajectories
- ...

- Cost
- Contact Sequence & Timing & CoM Trajectory & Leg Trajectories
- ...

Learning

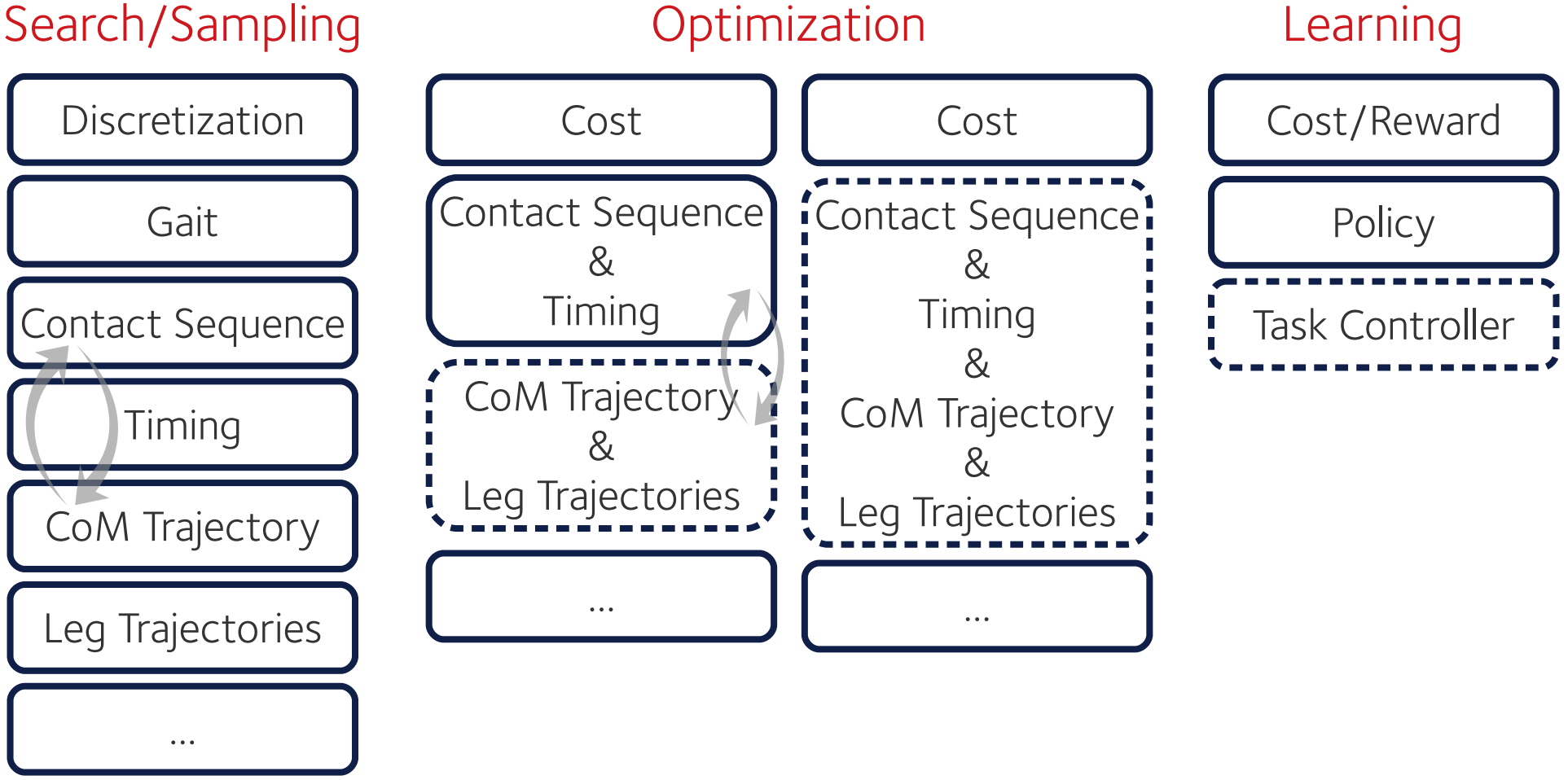
- Cost/Reward
- Policy
- Task Controller

ML Approach

+ Model free
+ Task spec.
+ General

- Training is hard (data, hw)
- Reward tuning
- Reality gap

Taxonomy


Search/Sampling
Discretization
Gait
Contact Sequence
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Leg Trajectories
...
Optimization
Cost
Contact Sequence & Timing
CoM Trajectory & Leg Trajectories
...
Cost
Contact Sequence & Timing & CoM Trajectory & Leg Trajectories
...
Learning
Cost/Reward
Policy
Task Controller

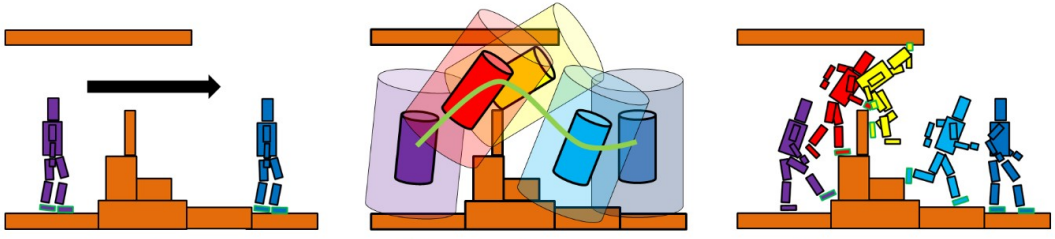
Mathieu Geisert

towr

Trajectory Optimizer for Walking Robots

"Gait and Trajectory Optimization for Legged Systems through Phase-based End-Effector Parameterization." Winkler, A. W, Bellicoso, D. C, Hutter, M, and Buchli, J. IEEE Robotics and Automation Letters (RA-L), 2018.

- Problems in optimization
  - Contacts
  - Phases
  - Friction Cones
  - … etc



(a) Initial request (b) Reachability planning (c) Contact sequence

"A Versatile and Efficient Pattern Generator for Generalized Legged Locomotion." Justin Carpentier, Steve Tonneau, Maximilien Naveau, Olivier Stasse, Nicolas Mansard. IEEE International Conference on Robotics and Automation (ICRA), May 2016.