

Novement

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Should we OPTIMISE or LEARN the movements of a robot ?



Predictive control



Decide: future robot trajectory

By optimizing an objective function (eg minimum energy)

Imposing:

- Known initial state
- Known evolution model (simulator)
- ... and other constraints



Original artwork by Michele Carminati, commissioned by Marco M. Nicotra (U. Colorado Boulder)

Predictive control



Artificial & Natural Movements

Toulouse Midi-Pyrénée

Efficient solvers ...

Features expected from a good optimal control solver

- Stable prediction: multiple shooting
- Sparsity: differential dynamic programming
- Strict constraints: augmented Lagrangian
- Our solver incorporates all three !

Performance on real case studies

- 4 trot cycles for a quadruped: 8K vars, 12 iterations, 9ms / iter
- 2 steps for a humanoid: 12K vars, 18 iterations, 13ms / iter







... for efficient problems



Efficient solver ... for efficient problems

Optimize 1 sec of preview every 1 ms (2000 variables)



Ludovic Righetti





Artificial & Natural Movements



$$\min_{\substack{X=(Q,\dot{Q}), \\ U=\tau}} \int_0^T l(x_t, u_t) dt$$

s.t. $x(0) = \hat{x},$
 $\dot{x}(t) = f(x(t), u(t)), \forall t=0..T$



Trajectory optimization $U: t \rightarrow u(t)$ Motion planning Policy optimization $\Pi: x \rightarrow u = \Pi(x)$ Reinforcement learning





Memory of motion

memmo









Memory reinforcement





Roadmap extension



HJB approximation Value function as metric Policy function as warm-start



Dataset of subtrajectories 10-100k items

> Regression (stoch.grad.)

Query



Neural network by supervised learning 2x512 hidden units Reinforcement learning with simulator gradients by:

1. Trajectory optimization

2. Supervised learning





We should both OPTIMISE and LEARN

the movements of a robot !

Trajectory optimization is necessary

- 10,000 variables in 10 ms
- Accurate convergence, constraints satisfaction, generalization

Policy learning is necessary

- Globalization using a memory of motion
- Toward super-linear reinforcement algorithms



ANITI : building hybrid intelligence







Artificial & Natural Movements

