Midterm – Presentation

Model-Based control approaches for the locomotion of legged robot

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The goal of this project is to incorporate the knowledge of the robot’s dynamics available in its model to improve controlling performance.

General requirement in motion of legged robots is **exact movement** while having as less contact forces as possible i.e. compliant control.
A brief literature review done over similar approaches:
- Virtual model control
- Potential field approach
- Impedance control
- Inverse dynamics control

Among these methods, Inverse dynamics can result in exact position control while minimizing contact forces.
The method is first used to control a Monoped robot. Then, it is extended to a quadruped one. What we need:

- The role of feed forward block is to give a good estimate of the forces required to follow a desired trajectory.

What we currently have:
- An open loop periodic solution optimized for energy
- Idea: use them as desired trajectories!
Step I. Implement Inverse Dynamics

- Contact forces depend on actuators and vice versa.
- A method decouples them

\[ M(q) \ddot{q} + h(q, \dot{q}) = S^T \tau + J_C^T(q) \lambda \]

\[ J_C^T = Q \begin{bmatrix} R \\ 0 \end{bmatrix} \]

\[ \tau = (S_u Q^T S^T)^+ S_u Q^T [M \ddot{q}_d + h] \]

- We feed the system the calculated torques from desired trajectories we have.
- Does it work forever? Stability?
Step I: Implement Inverse Dynamics

- Desired
- Output

Can’t continue forever!
Rough terrains?
Hybrid states?
Other scenarios?
Step II. Trajectory planner

- How could we modify trajectories?
- Idea: use known trajectories + transitions
- @ Fly: control attack angle = $\alpha \times$ horizontal speed
  Feedback
- @ Stance: control $\phi = 0$
  Feedback + feed-forward
- Idea of soft transition: at phase changes, preserve previous variable and its derivative while forcing desired trajectories
- Exponential choice has damping property.

$$q_{new}(t - t_0) = a(t - t_0) \times q_{old}(t - t_0) + b(t - t_0) \times q_{desired}(t - t_0)$$

$a(0) = 1, a(T) = 0, b(0) = 0, b(T) = 1$
$\dot{a}(0) = 0, \dot{a}(T) = 0, \dot{b}(0) = 0, \dot{b}(T) = 0$

$$a(t) = e^{-(t/\tau)^2}$$
$$b(t) = 1 - e^{-(t/\tau)^2}$$
Structure of controller:
Step II, Trajectory planner

- Desired
- Output

Stance
Step II. Trajectory planner

Phase 1, Stance

Phase 2, Fly

Quick damping

Slow damping

Soft transitions
Step II: Trajectory planner

- Steady State Forces/Torques

For $\phi$

For $l$

Stance
Step II: Trajectory planner

- natural moving on a rough terrain
Step III. High level planner

- Need to modify trajectories to Handle:
  - More complex terrains like stairs, ramps
  - uncertainties
- Idea: Incorporate a high-level Self Organized Controller

\[ y_{\text{desired, modified}}(t - t_0) = (y_{\text{desired}}(t - t_0) - \text{bias}) \times (1 + |u|/5) + \text{bias} \]
\[ \phi_{\text{desired, modified}}(t - t_0) = 0 + u \]
Step III, High level planner

1. Double slopes scenario
Step III. **High level planner**

2. Controlling over average speed
To be done ...

- Possibly on monoped:
  - Switch to change attack angle with high-level controller
  - Comparison to similar works

- Switch to quadruped:
  - Implement Inverse dynamics
  - Adjust weightings so that feed-forward solution adapts to imposed conditions
  - Defining transitions
  - Use of operational space controllers to have more meaningful transitions
  - Incorporating the high-level controller
Thank you!
Any question?
Fuzzy SOC

Performance measure

Model

Rule modifier

Credit assignment
**Fuzzy SOC**

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### Performance Measure

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