Motion control bits for homemade robots

Stéphane Caron

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Morphology

Blast from six years ago



Video memories: https://youtu.be/8P9geWwi9e0

Joint control	Sensors	State observation	Whole-body control	Example
Torque	Joint torques	Heavier	Impedance $*$	Atlas
Position	Force sensors	Lighter	Admittance	Hubo

^{*} With leaky integrators, no passivity yet.

Here come the wheels



Handle



ANYmal on Wheels



Ascento

See also a great explorator of new morphologies: https://www.youtube.com/user/jamesbruton

Joint control	Sensors	State observation	Whole-body control	Example
Torque	Joint torques	Heaviest	Impedance	Atlas
Position	Force sensors	Lightest	Admittance	Hubo
Torque	Joint torques	Middle ground	Impedance	Ascento
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Whole-body control of Ascento: https://arxiv.org/pdf/2005.11431.pdf

Building our own

Off-the-shelf actuators

Quasi-direct drive:

- Ben Katz's design for the Mini Cheetah
- Commercially available: mjbots, MAB, ...
- Torque range: cont. 6 Nm, peak 16 Nm
- Price range: 400-600\$

Series-elastic:

- Gill Pratt's design from the 90's
- Commercially available: HEBI
- Torque range: cont. 10 Nm, peak 20 Nm
- Price range: 3000-4000\$





Ben Katz's blog: https://build-its.blogspot.com/

mjbots stack



Home Products - Full Catalog About -

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qdd100 beta 2 developer kit

\$499.00











mjbots pi3hat r4.4b from \$149.00

mjbots power dist r4.3b \$139.00

fdcanusb \$109.00

\$439.00



moteus r4.11 controller \$104.00



mj5208 brushless motor \$60.00

Store: https://mjbots.com/

Upkie

Wheeled biped:

- Joints: 6 (hips, knees, wheels)
- Total mass: 5.4 kg
- Print time: 33 h 14 min
- Knee torques: 2.0 Nm crouched
- Wheel torques: $0.2 + f(\alpha)$ Nm
- Autonomy: 3-4 h with 5.0 Ah battery
- Actuators + electronics: 2,400 €



Project page: https://hackaday.io/project/185729-upkie-homemade-wheeled-biped-robot

Electronics



Raspberry Pi hat: https://github.com/mjbots/pi3hat

How to share hardware?

Pros:

- Reproducibility: available to others by online retail with public prices (no quote!)
- Maintain availability under chip shortages
- Open source options (*e.g.* mjbots)

Cons:

- Companies go out of business more often than not
- Net loss if closed source (e.g. ODrive)

Printables



https://www.printables.com/model/127831-upkie-wheeled-biped-robot

← → C @ O A https://tasts-robots.org

Tast's Robots

Homemade robots, open source thinkers, living room roamers.

Homemade robots

We are homemade robots built with the parts and tools hobbyists can readily get from DIV stores, or ordering online. You don't need expert training to build us. Just tools, a bag of metric screws and a taste for:

- 3D printing
- · JST cables and crimping
- XT cables and soldering

Open source libraries

Our software is open source and made of libraries, not a framework. They should run on your robot tool Most of our code is in Python, including locomotion control, and we don't rely on precise models. Check out our code and let us know if it works for you:

- Inverse kinematics
- Real-time control for Raspberry Pi

Locomotion for all

Locomotion is not rocket science: it doesn't require huge investments. Saw some broomsticks, cable actuators together, plug in the software and roll! Haven't tried yet? Check out our videos and ask questions: ★ 🗶 =

- Locomotion code
- YouTube channel
- Article: How do biped robots walk?

Proposed definition: https://tasts-robots.org/ \leftarrow feedback welcome!

How to share software?



Aim for incremental buy-in.

Repositories: https://github.com/tasts-robots

Pink

Task-based inverse kinematics:

- Long-lasting yet still active question
- Combine tasks by weights into a single QP
- Tikhonov and Levenberg-Marquardt damping

Open questions:

- Frequency-independent formulation?
- Eliminate damping parameters?
- Avoid instability near almost-feasible targets? (\star)



Distribution: pip install pin-pink



- Balance control at low frequency (Python)
- Convert actions to servo commands at medium frequency (C++)
- Actuators run field-oriented control on-board at high frequency (C++)

Balancing is a low-frequency task: https://arxiv.org/pdf/1907.01805.pdf

Wheeled biped observers



Code: https://github.com/tasts-robots/upkie_locomotion

Wheel contact observation



https://tasts-robots.org/doc/upkie_locomotion/classupkie_locomotion_1_1observers_1_1WheelContact.html

- It has become easier to try new morphologies.
- Sharing hardware: reproducibility requirements.
- Sharing software: incremental buy-in

Thank you for your attention!



These slides include feedback from Vincent Padois and Grégoire Passault, thanks!