Not All Physics Simulators Can Be Wrong in the Same Way

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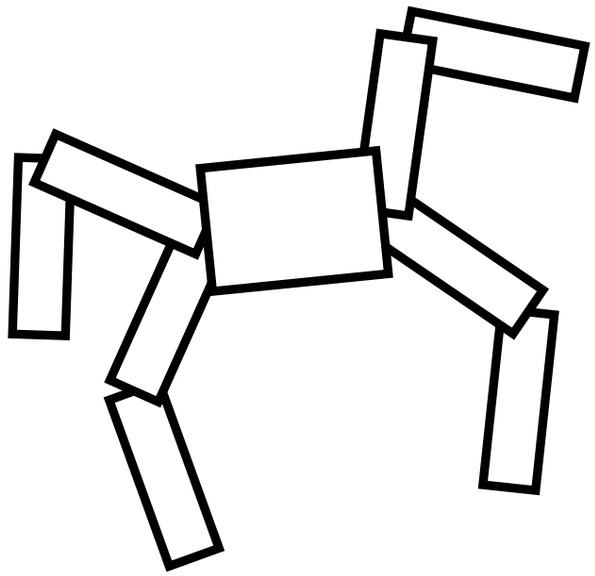
Idea

- Can multiple physics simulators help us cross the reality gap?

Goal



- Evolve robot controllers

Why Simulate?

- Fast
- Cheap
- Noiseless (or noisy)
- Controlled environment

Why *Not* Simulate?

- Real motors behave differently than simulated motors
- Real sensors behave differently...
- Real world behaves differenly
- No guarantee of transference

Solutions

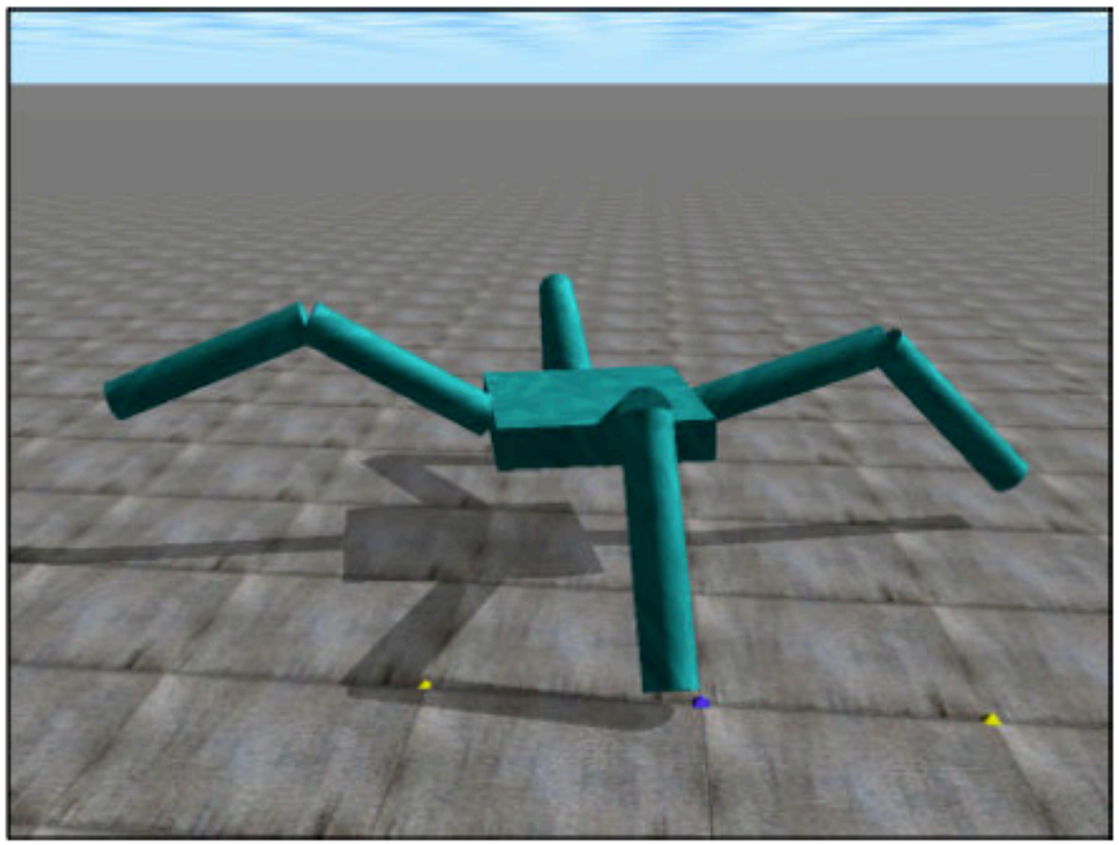
- Evolve on hardware (Hornby et al, 2000)
- Minimal simulation, LOTS of noise (Jakobi, 1998)
- Forget momentum, use quasi-static simulator (Pollack and Lipson, 2000)
- Fine-tune evolved design on actual hardware (Pollack et al, 2000)
- Simulation To Reality (STR) disparity (Koos, Mouret, and Donceiux, 2010)
- Evolve your simulation (Bongard, 2006)

Proposed Solution

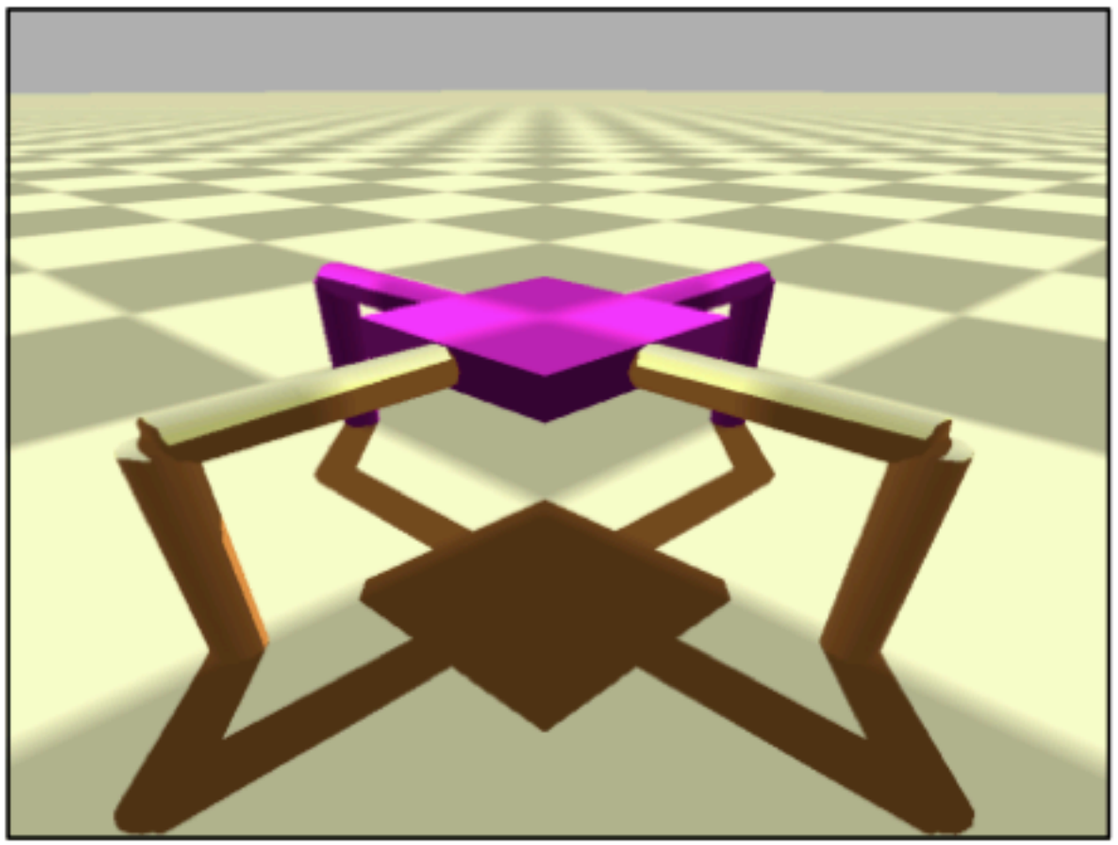
- Use more simulators
- Each approximate the real world
- All fail
- Distinct failures can check other simulators

Method

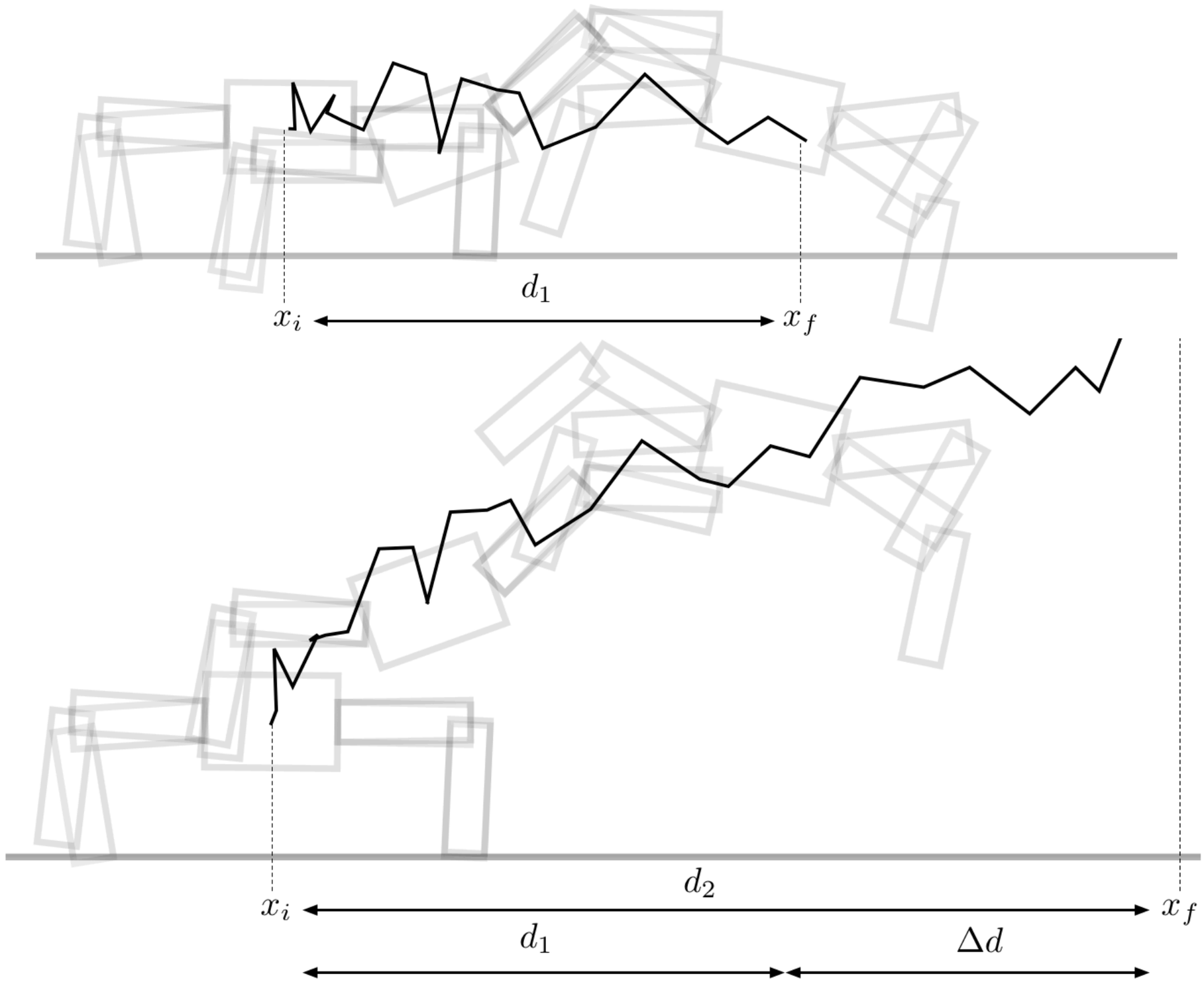
a)



b)



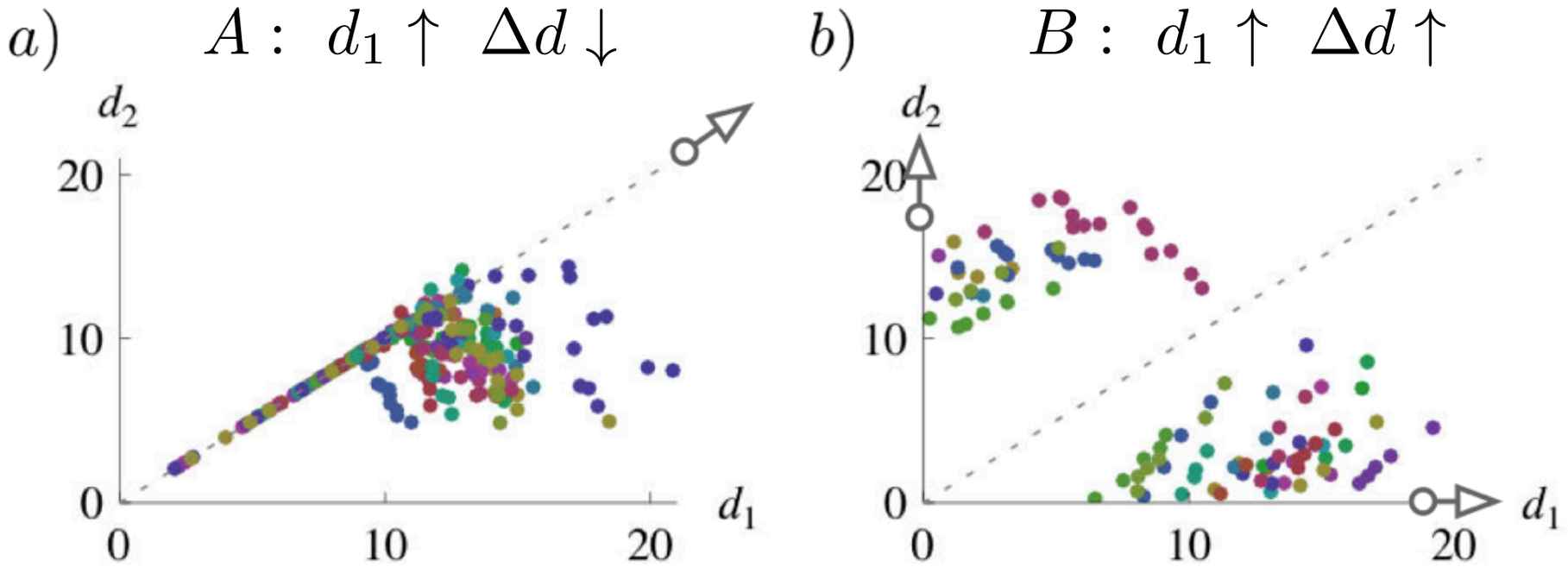
Fitness

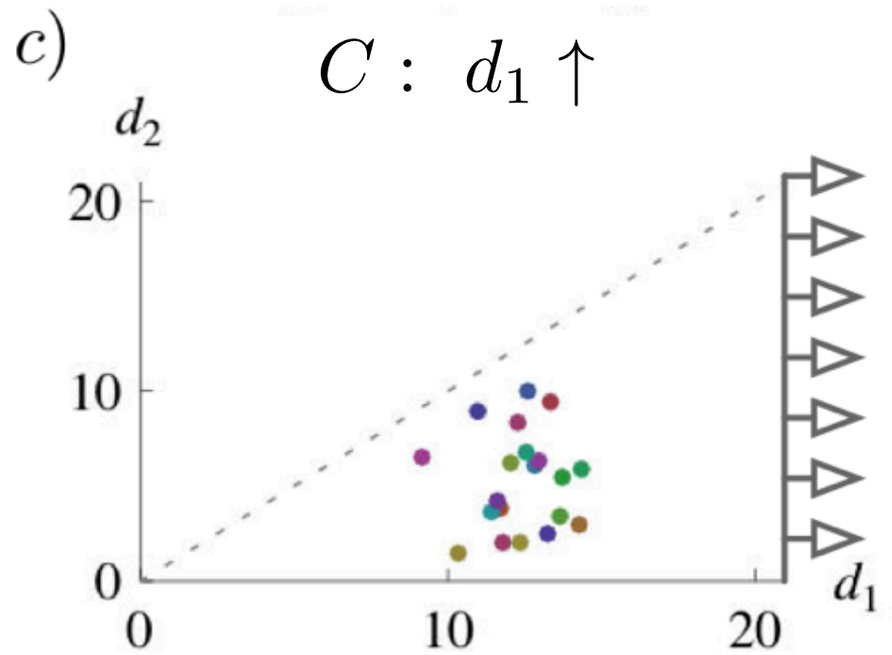


Experiments

- A: Maximize d_1, minimize $|\Delta d|$
- B: Maximize d_1, maximize $|\Delta d|$
- C: Maximize d_1 (control)

Results

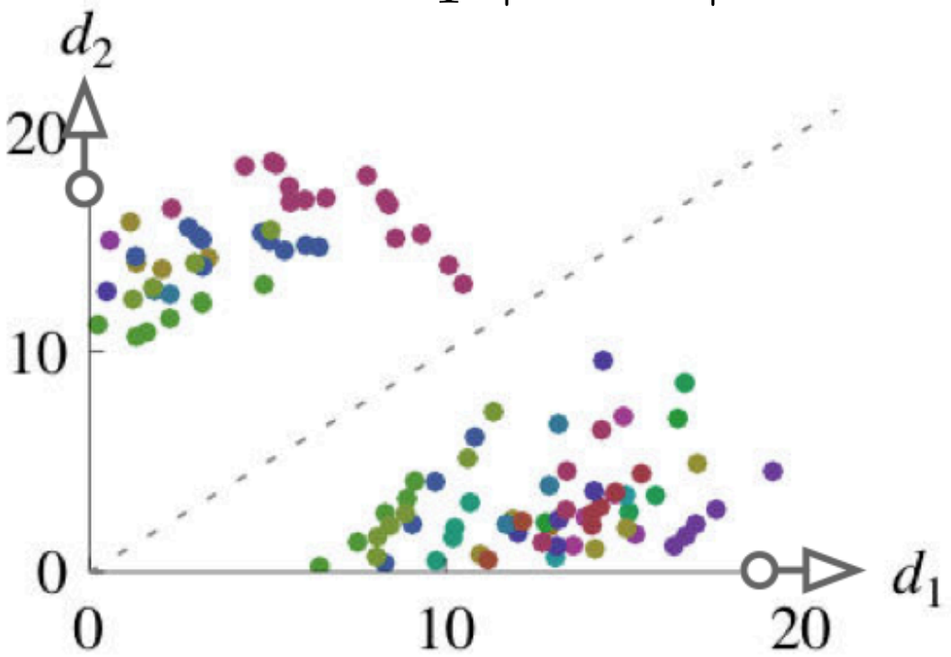

a)
$A:\ d_1 \uparrow\ \Delta d \downarrow$
b)
$B:\ d_1 \uparrow\ \Delta d \uparrow$
d_2
20
10
0
0
10
20
d_1


c)
$C:\ d_1 \uparrow$
d_2
20
10
0
0
10
20
d_1

Curious

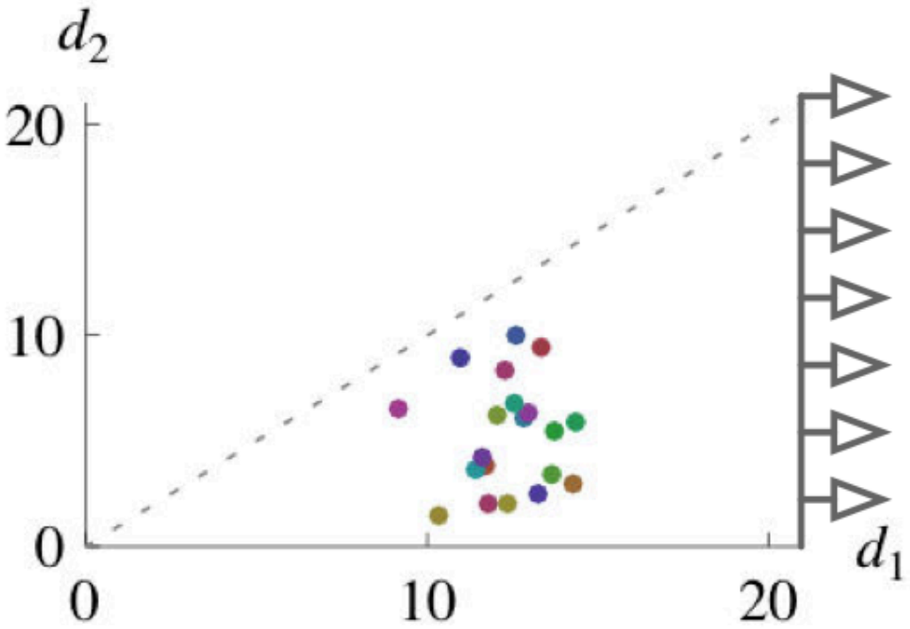
b)

$B:\ d_1 \uparrow\ \Delta d \uparrow$

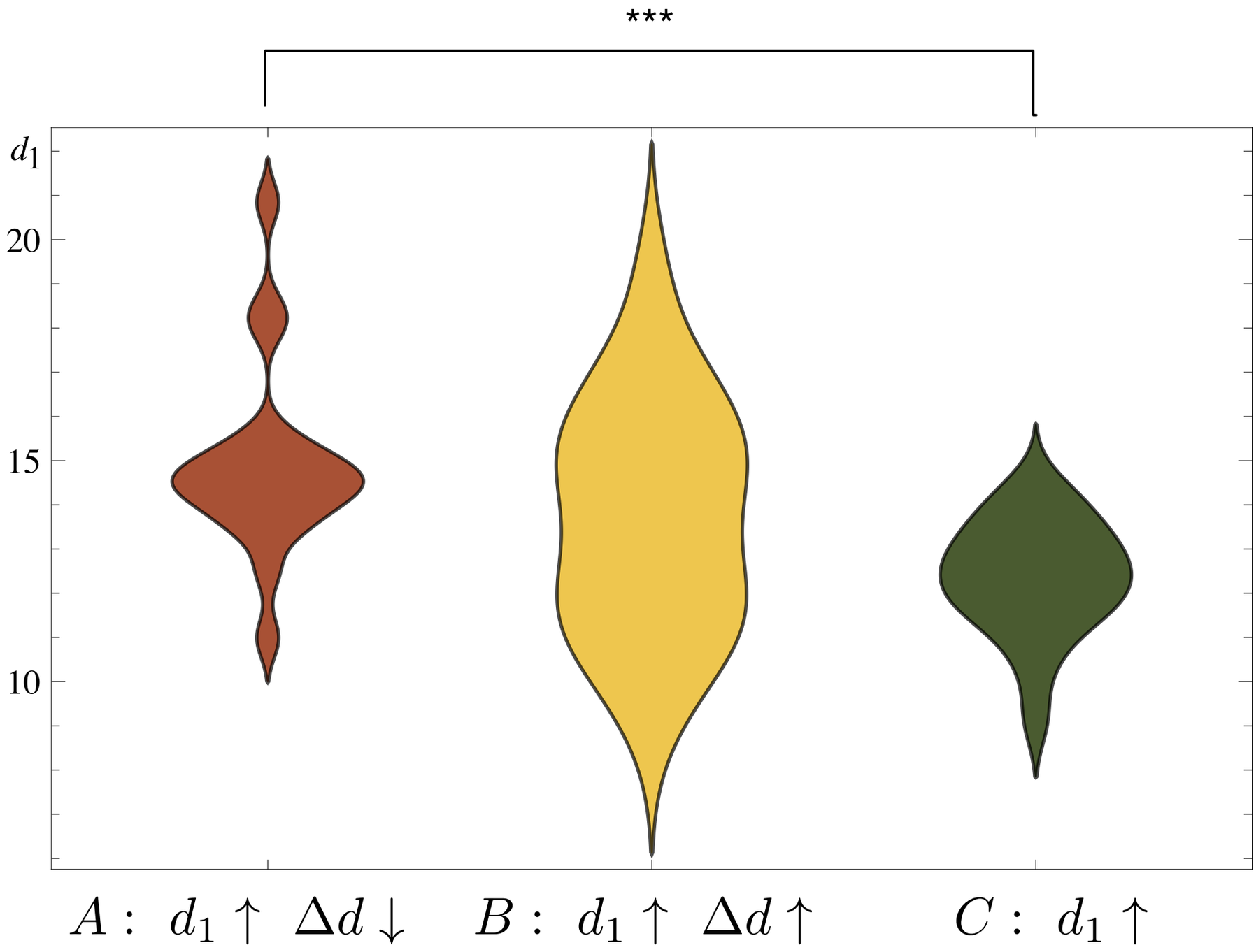


c)

$C:\ d_1 \uparrow$



Best Individuals

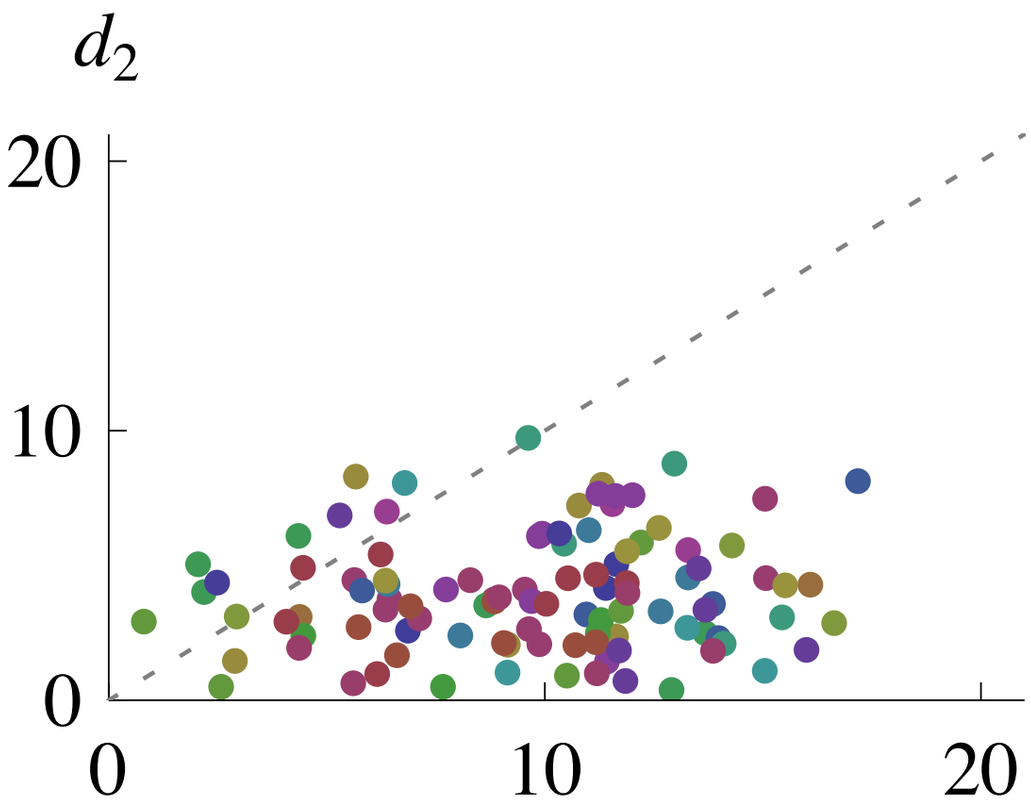


Follow Up Experiments

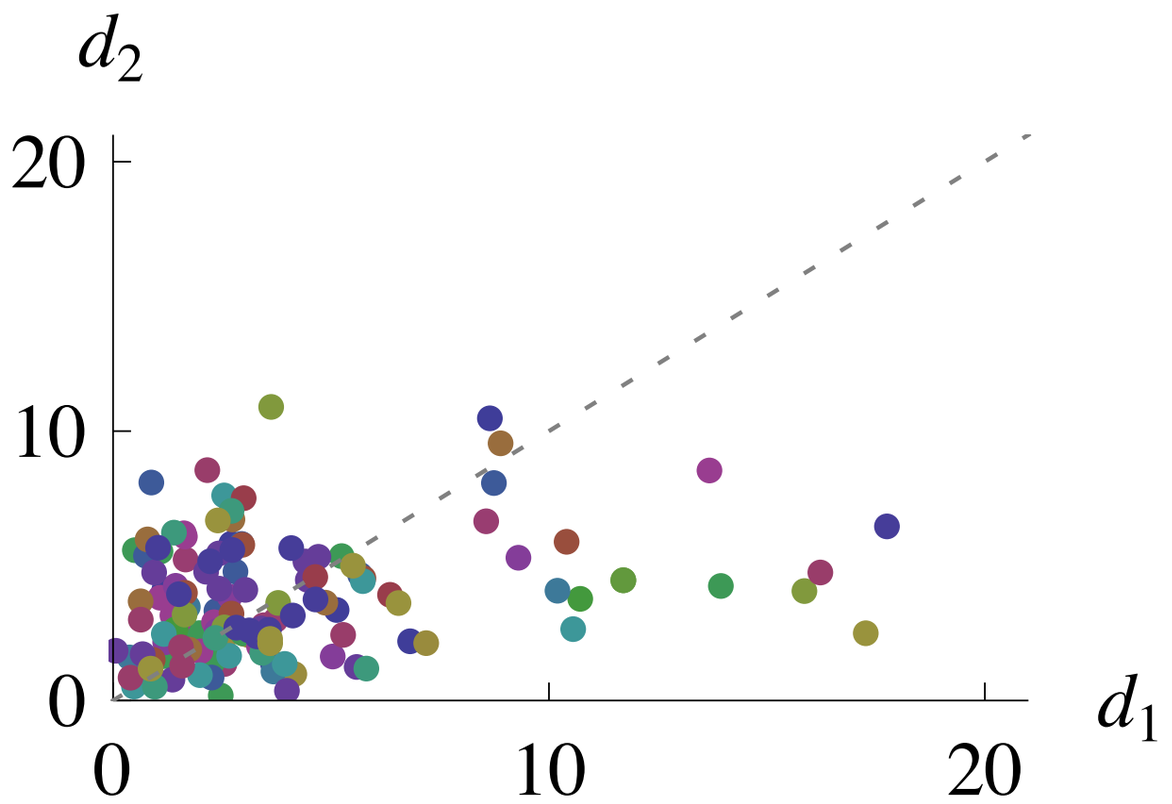
- D: Maximize d_1, minimize random number R
- E: Maximize d_1, minimize non-functional gene G

Results

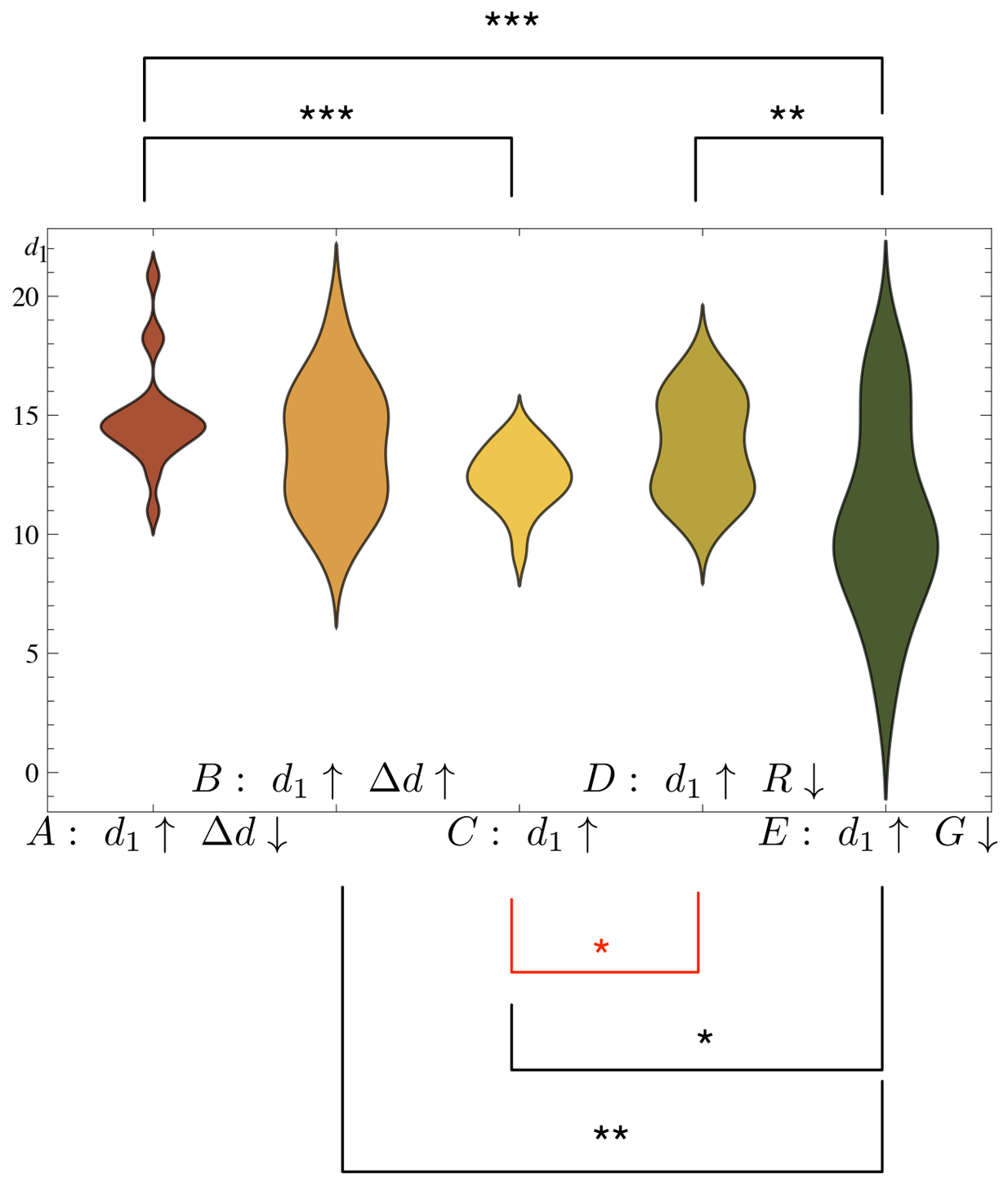
$D: \ d_1 \uparrow \ R \downarrow$



$E: \ d_1 \uparrow \ G \downarrow$



Follow Up Results



Future Work

- Test with n simulators using PAL
- Use time series data/behavioral data instead of fitness values (a la STR)
- Experiment on real robot

Thanks!

- Questions?

Build your own quadruped

ODE and Bullet instructions:

http://uvm.edu/~ludobots