Controls Overview

Project Stompy the Hexapod
Dan Cody — 5/1/2012

- Body morphology
- Leg morphology
- Actuation
- Sensing
- Computation
- Control

already covered {

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Requirements

Given…

- 19 people
- 16 weeks
- $11,000

Build a hexapod that…

- Looks awesome
- Is ridable
- Can walk in a parade

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Build a hexapod that…

- Looks awesome
- Is ridable ← drives payload
- Can walk in a parade ← implies:

walks at human speed, safe to operate near people, operates on paved streets, does not damage paved streets, can walk over potholes and curbs, can walk up and down hills, can stop quickly, fuel lasts for at least one hour, breakdowns are rare, recovery from a breakdown is easy, ...

Requirements

Key drivers:

- Safety
- Resources
- Operating in unstructured environments

Reality check

$$\frac{\text{3 weeks}}{\text{16 weeks}} \approx \text{20\% gone}$$

$$\frac{\$7{,}000}{\$11{,}000} \approx \text{65\% spent}$$

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I hope you find this slide scary.

So let's not waste time!

- Body morphology
  6 legs are required for a static gate
- Leg morphology
  3 joints are required to place the foot in a volume
- Actuation
  Hydraulics are good at high forces
  Proportional valves support a range of flow rates

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Sensing, Part 1

We need to know where the foot is

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Use GPS

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We need to know where the foot is

to within 5 cm, updated at 100 Hz

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Use 3-axis accelerometer

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relative to body, with low drift, high shock resistance

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Use 3-axis accelerometer

Use potentiometers on the joints

Sensing, Part 1

We need to know where the foot is

to within 5 cm, updated at 100 Hz
relative to body, with low drift, high shock resistance
low temperature sensitivity, low backlash, cheap, robust

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Use 3-axis accelerometer
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Sensing, Part 1

We need to know where the foot is

to within 5 cm, updated at 100 Hz
relative to body, with low drift, high shock resistance
low temperature sensitivity, low backlash, cheap, robust

Use GPS

Use 3-axis accelerometer

Use potentiometers on the joints

Use magnetic encoders on the joints

Sensing, Part 2

We need to know where the ground is

Do we need to measure interaction forces?	Strain gauges
Do we need to measure joint torques?	Hydraulic pressure gauges
Do we just need a touch-down sensor?	Compliant element with rotary encoder

Sensing, Part 2

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Do we need to measure interaction forces?	Strain gauges hysteresis, calibration, temp. coeff.
Do we need to measure joint torques?	Hydraulic pressure gauges cost
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Sensing, Part 2

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Do we need to measure joint torques?	Hydraulic pressure gauges cost
Do we just need a touch-down sensor? We hope!	Compliant element with rotary encoder

Sensing, Part ?

More information is more better (resources allowing)

- IMU to detect orientation of body
- Infra-red camera on each leg to detect humans under-foot
- Microphone to detect impact/screams
- Others?

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Computation

- Read encoders
- Collect readings at a CPU
- Do some math
- Distribute flow-rate commands
- Force current through the valves

Computation

- 8-bit PSOC μControllers at joints and valves
  Cheap, "reconfigurable" analog hardware
- Talk to CPU using RS-422
  2-wire differential bus
  Transceivers readily available
- CPU is a desktop running Ubuntu
  We hope it's robust enough!
- Code is in python whenever possible
  Trade efficiency for shorter development time

Aside: Applied math

```
  10000000000000001.0
 −10000000000000000.0
 ────────────────────
                  1.0
```

Aside: Applied math

```
 10000000000000001.0
-10000000000000000.0
--------------------
                 1.0
```

```
dan$ python
>>> 10000000000000001.0 - 10000000000000000.0
0.0
>>>
```

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- **Control**

Control

solved problems

- Joint position control
- Kinematics
- Trajectory tracking

problems you should spend lots of time thinking about

- Gait design
- Sensor validation
- Hexanaut interface

Control: Tripod gait

- Two simultaneous phases, three legs each
- Legs contacting the ground are constrained
- Legs that are recovering can take any path
- The phases must overlap somewhat

Control: Tripod gait

- Is there an efficient way for legs to recover?
- How high do the feet need to step?
- How much overlap is needed?

Control: Tripod gait

“efficient” means “lowest peak flow-rate”

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Control: Tripod gait

"efficient" means "lowest peak flow-rate"

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foot needs to: get up to speed, descend unknown distance to the ground, allow the trailing foot to leave the ground, leave enough time to decelerate the body if something goes wrong

Go build a hexapod.