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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• Leg morphology
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• Sensing
• Computation
• Control
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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{these are very limiting}
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Build a hexapod that...

• Looks awesome
• Is ridable  drives payload
• Can walk in a parade
Requirements

Given...

- 19 people
- 16 weeks
- $11,000

Build a hexapod that...

- Looks awesome
- Is ridable \(\Rightarrow\) drives payload
- Can walk in a parade \(\Rightarrow\) 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

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

\[
\frac{$7,000}{$11,000} \approx 65\% \text{ spent}
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Stompy $\ll 20\% \text{ done}$
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Stompy \ll 20\% \text{ done}

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
• Body morphology

• Leg morphology

• Actuation

• **Sensing**

• Computation

• Control
Sensing, Part 1

We need to know where the foot is
Sensing, Part 1

We need to know where the foot is

Use GPS
Sensing, Part 1

We need to know where the foot is to within 5 cm, updated at 100 Hz

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Sensing, Part 1

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Use GPS

Use 3-axis accelerometer
Sensing, Part I

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

Use GPS
Use 3-axis accelerometer
Use potentiometers on the joints
Sensing, Part I

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
Sensing, Part I

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

<table>
<thead>
<tr>
<th>Question</th>
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### Sensing, Part 2

Do we need to measure interaction forces?

- **Strain gauges**
  - hysteresis, calibration, temp. coeff.

Do we need to measure joint torques?

- **Hydraulic pressure gauges**
  - cost

Do we just need a touch-down sensor?

- **Compliant element with rotary encoder**

  We hope!
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?
• Body morphology
• Leg morphology
• Actuation
• Sensing

• **Computation**
• Control
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

\[
\begin{array}{c}
100000000000000001.0 \\
-100000000000000000.0 \\
\hline
1.0 \\
\end{array}
\]
Aside: Applied math

\[
\begin{align*}
\phantom{-}10000000000000001.0 \\
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Control

- Joint position control
- Kinematics
- Trajectory tracking
- Gait design
- Sensor validation
- Hexanaut interface

solved problems

problems you should spend lots of time thinking about
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

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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.