

Robots With Legs

Helge Wrede

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Outline

Motivation

Overview

Properties

- Number of legs

- Balance

- Walking

Basic Bipedal Implementation

Dynamic Balancing

- Concepts

- 3D-LIPM

Motivation

CASSIE



Figure: Side view of the Robot Cassie from Agility Robotics [Shelton et al., 2017]

Overview

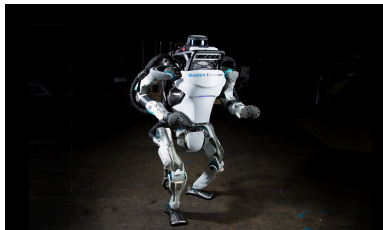
Why legs?

- ▶ World built for humans
- ▶ Versatility

Properties

- ▶ Number of legs
- ▶ Gait
- ▶ Balance
- ▶ Power usage
- ▶ Precision

Number of legs



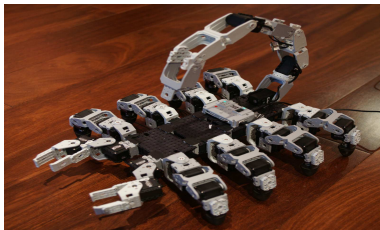
(a) Bipedal [Simon, 2017]



(b) Quadruped [McGlaun, 2017]



(c) Hexapod [Elijah, 2017]



(d) Octopod [encrust1, 2012]

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Balance



Figure: Example of a hexapedal robot with static balance [Lopes, 2008]

Balance

Static

- ▶ Stable all the time
- ▶ Achieved by leg positioning
- ▶ Easy to control
- ▶ At least 4 legs are required

Dynamic

- ▶ Only stable in specific configurations
- ▶ Achieved by active balancing
- ▶ Hard to control
- ▶ Arbitrary number of legs

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Walking

Active

- ▶ Driven by motors
- ▶ High precision controlling required
- ▶ High power usage

Passive

- ▶ Driven by gravity
- ▶ No controlling needed
- ▶ No power usage

Passive Walkers

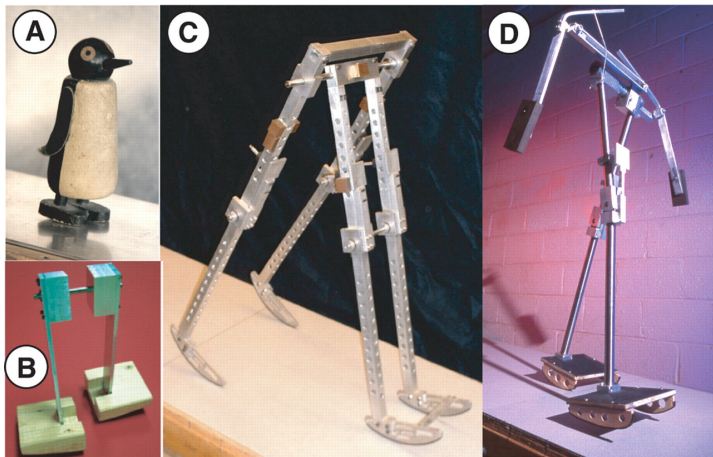


Figure: Multiple passive walker examples [Collins et al., 2005]

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Basic Bipedal Implementation

Start with passive walker prototype

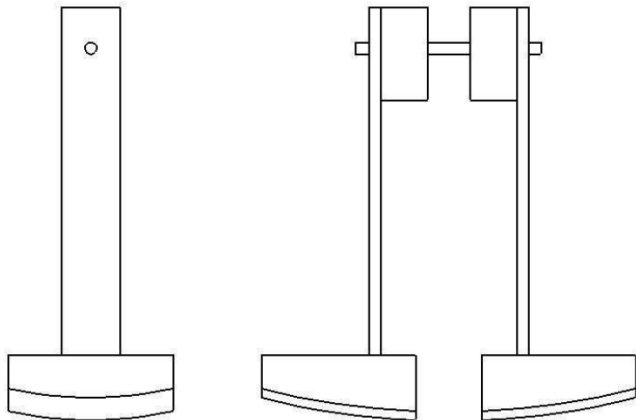


Figure: Passive Walker Prototype [Fong, 2005]

Basic Bipedal Implementation

Add artificial gravity employing motors and controllers

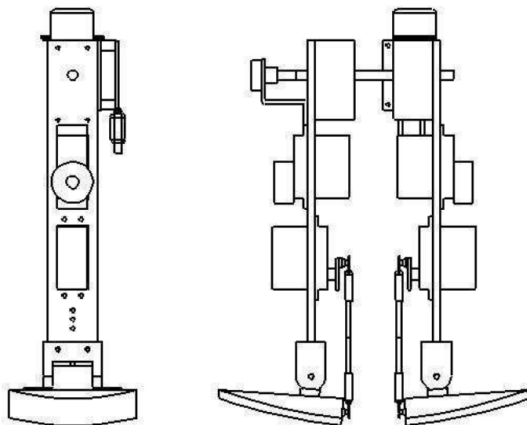


Figure: Motorized Passive Walker [Fong, 2005]

Basic Bipedal Implementation

Get Combined Walker

- ▶ Low power usage
- ▶ Easy to control
- ▶ Enables smooth motion
- ▶ Might utilize active balancing to improve stability

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Concepts

- ▶ Center of Mass
- ▶ Support Polygon
- ▶ Zero Moment Point
- ▶ Stability Region
- ▶ Inverted Pendulum

Dynamic Balancing

3D Linear Inverted Pendulum Model

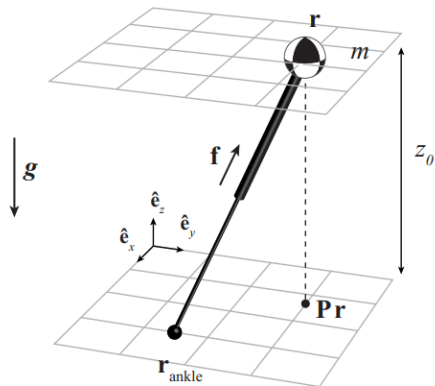


Figure: Simple schematic representation of a 3D linear inverted pendulum
[Koolen et al., 2012]

Dynamic Balancing

3D Linear Inverted Pendulum Model

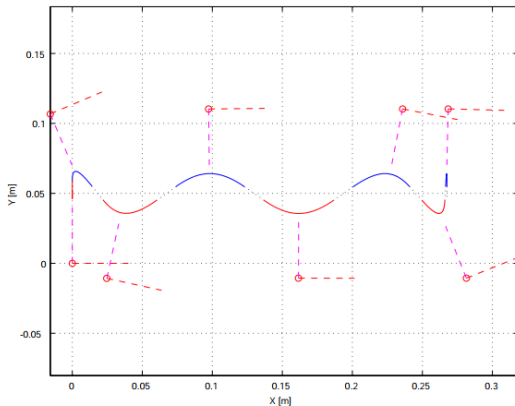


Figure: Topview of a generated walking pattern for a straight line
[Kajita et al., 2001]

Dynamic Balancing

3D Linear Inverted Pendulum Model

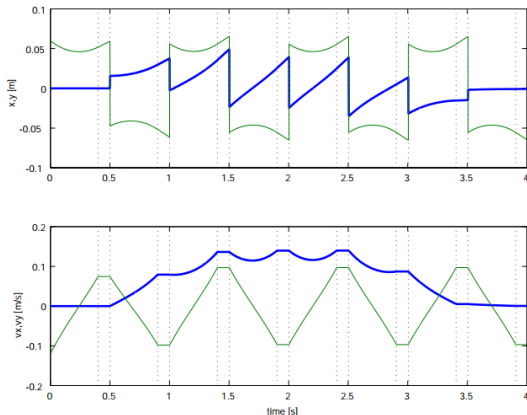


Figure: Topview of the motion and acceleration of the point mass of a generated walking pattern for a straight line [Kajita et al., 2001]

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Appendix - Passive Walkers

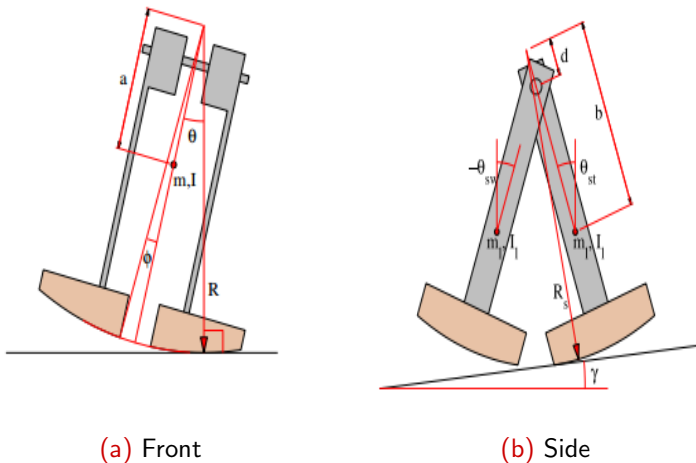


Figure: Schematic of a passive walker seen from the front and from the side on a slope [Fong, 2005]

Appendix - Dynamic Balancing

3D Linear Inverted Pendulum Model

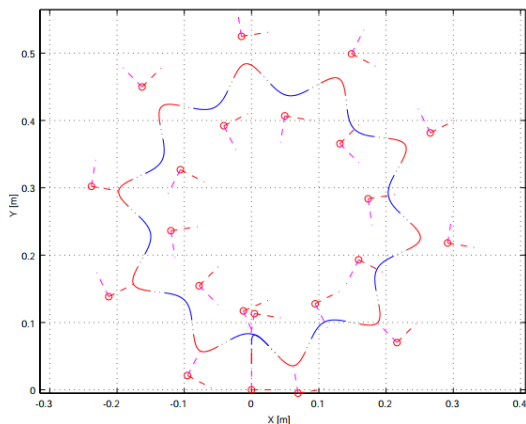


Figure: Topview of a generated walking pattern for a circle
[Kajita et al., 2001]

Appendix - Dynamic Balancing

3D Linear Inverted Pendulum Model

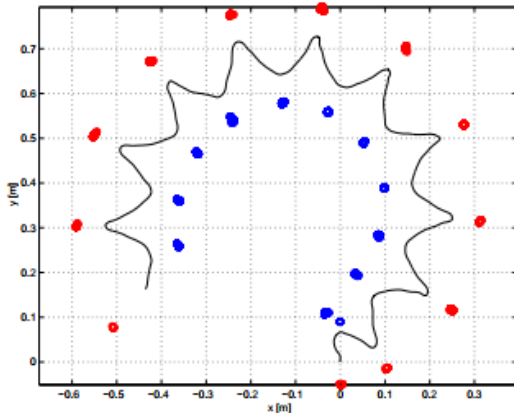


Figure: Topview of the simulation results based on the previously generated walking pattern for a circle [Kajita et al., 2001]