

Development and implementation dynamic balance algorithms for bipedal robot locomotion

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Introduction and Motivation: the development of robotics in minds

Trends in robotics are near to be developed.



Forbidden
planet, 1956



RoboCop,
1987



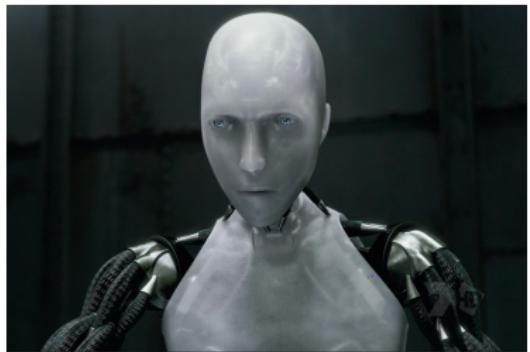
Bicentennial
man, 1999

Introduction and Motivation: the development of robotics in minds

Robotics, Cybernetics, Biomechatronics, AI are only several of prospectives that are required to take into account in bipedal robots development.



Terminator, 1984



I, robot, 2004

Introduction and Motivation: humanoid robots development



ASIMO
<http://www.honda.co.jp/ASIMO/>

Humanoid robot definition

- Mechanism with body structure resembles that of a human: head, torso, legs, arms, hands
[Hirai et al.(1998) Hirai, Hirose, Haikawa, and Takenaka]

Why humanoids ?

- Ability to work directly in the same human environment without any modification
- General-purpose workers
- Social integration
- Work with same tools as humans

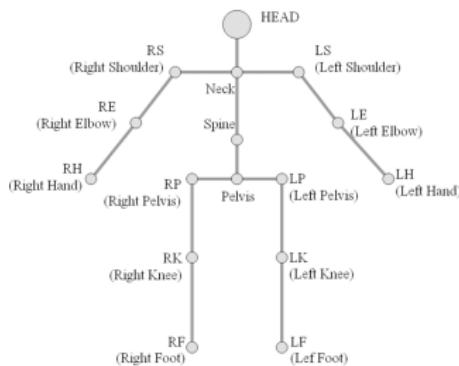
Humanoids Advantages and Disadvantages

- (+) Universal environment
- (+) Natural, human-like
- (+) Uneven terrains
- (-) Difficult locomotion
- (-) Complex design
- (-) Low speed
- (-) Complex control
- (?) Special tasks cannot be performed by general robots as good as by devices that were designed for this proper task.

Problem Overview

Bipedal locomotion difficulties

- Humanoids are underactuated due to inertia frame
- Difficult to solve Inverse Kinematics
- Several kinematic chains
- Requires the robot to plan motions



Human as a kinematic chains [Seo et al.(2011)Seo, Lee, and Choi]

Bipedal locomotion control approaches

- Analytical approach (ZMP based and others)
- Central Pattern Generator approach
- Neural Networks approach
- Hidden Markov Model approach
- Rule based approach

Steps required for bipedal locomotion

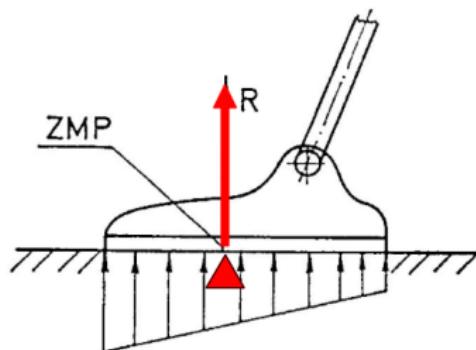
- Apply stability constraints
- Design a gait algorithm
- Solve remaining Degrees of Freedom

Stability measures

- Zero Moment Point (ZMP)
- Foot Rotation Indicator (FRI)

ZMP

- The distributed floor reaction force can be replaced by a single force R acts on Zero Moment Point



Zero Moment Point (ZMP), [Vukobratović and Borovac(2004)]

Human walking process

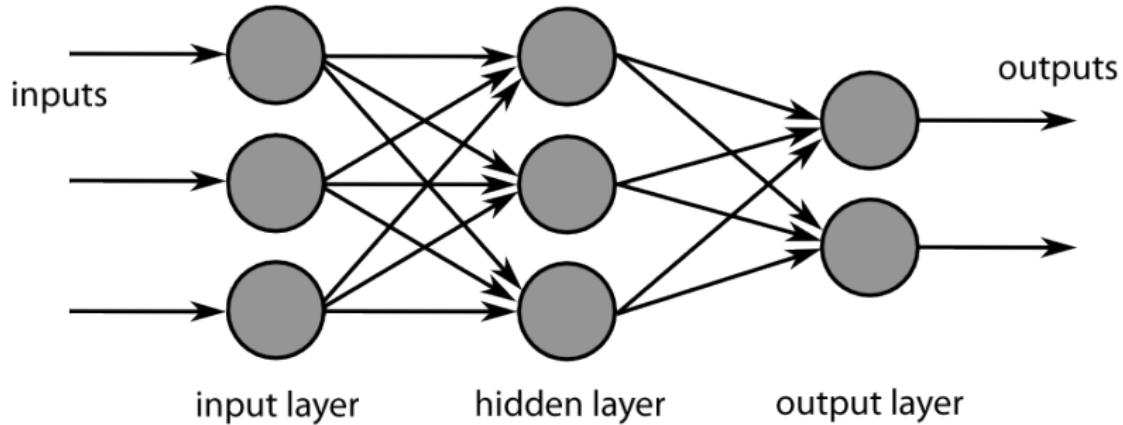
- Rhythm generating
- Control and adaptation mechanism

CPG principle

- Biological CPGs are made from pairs of mutually inhibiting neurons
- Pairs of mutually inhibiting neurons are described by systems of differential equations
- CPG is a neural network working without input

Related work: Neural Networks Approach

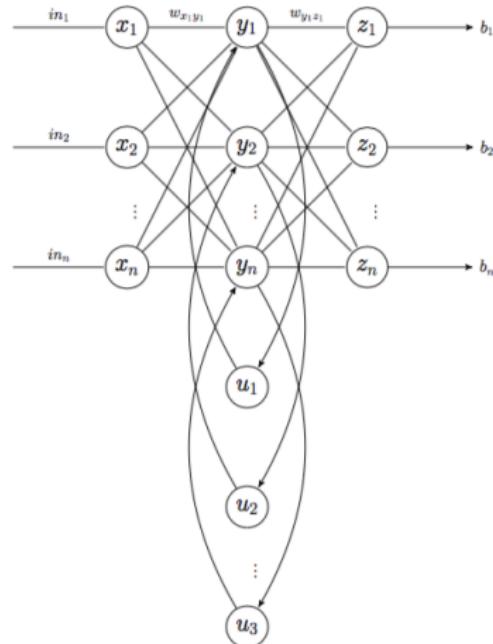
Feed-Forward Networks



Feed Forward Network [Kim et al.(2012) Kim, Kim, and Park]

Related work: Neural Networks Approach

Recurrent networks



Elman Recurrent Network

HMM for bipedal locomotion algorithm

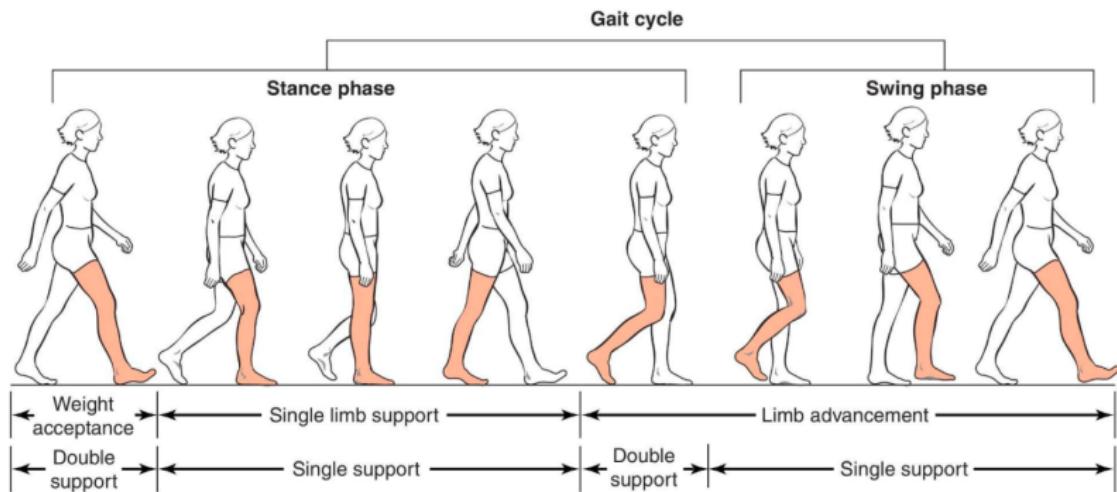
- A correspondence between the control signal and controller input
- The control signal depends only on a finite number of previous input signals
- Define a set of patterns
- Set of input signals is mapped to the set of possible control signals
- Train the model by the data describing control signals
- Collect a set of trained models

Rule Based Approach principle

- Divide the set of all possible system configurations into the clusters
- For each cluster assign the control function
- During the work control function will be chosen according to the current robot configuration
- Current configuration defines the possible control function
- Fuzzy logic controller is a perspective approach for solving dynamical stability problem
- Fuzzy logic controller divide all the configuration space into the subspaces
- For each subspace control function is defined in an optimal way

Theoretical aspects of bipedal robots control

Locomotion is a periodic gait cycle.



Gait cycle decomposition [Hill(2015)]

Cart table model



Summary



Thanks for the attention

Now it's time for your questions

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