Neural Control for Locomotion of Walking Machines
From Biological Inspiration to Implementation on the Machines
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Presentation outline
- Biological locomotion control
  - Central Pattern Generator (CPG)
  - Reflexes (local motor response to a local sensation)
  - Higher control centers (brain for e.g., posture, direction)

Biological locomotion control
Biomechanics:
Neural control:
- Central Pattern Generator (CPG)
- Reflexes (local motor response to a local sensation)
- Higher control centers (brain for e.g., posture, direction)

Sensor-driven neural control of the six-legged walking machine AMOS
Modular design
Modular neural network

The thoraco-coxal (TC-) joint enables forward (+) and backward (−) movements.
The coxa-trochanteral (CTr-) joint enables elevation (+) and depression (−) of the leg.
The femur-tibia (FTi-) joint enables extension (+) and flexion (−) of the tibia.

Neural oscillator network (CPG)

Velocity regulating network (VRN)

Phase switching network (PSN)

Motor neurons

Neural parameters for generating different walking patterns

At least 12 actions!!!

FL, FR CL, CR TL, TR

Forward:
I1 = 0, I2 = 1, I3 = 1, I4 = −1, I5 = −1

Turn right:
I1 = 0, I2 = 1, I3 = 1, I4 = −1, I5 = 1

Omnidirectional walking

Sensor–driven neural control

Versatile reactive behaviors: Reflex, escape, obstacle avoidance and phototropism behaviors
Adaptive reflex neural control of the biped robot RunBot

Nested-loop design

Special features:
- Small, curved feet allowing for rolling action;
- Unactuated, hence light, ankle;
- Lightweight structure;
- Light and fast motors;
- Proper mass distribution of the limbs;
- Properly positioned mass center of the trunk.

The RunBot system has been originally developed by Dr. Tao Geng.

Spinal reflex (Relexive neural network)

Joint control (Spinal 1)

Inter-joint control (Spinal 2)

Leg control (Spinal 3)

Motor neurons

Passive walking properties (Biomechanical design)

Changing speed on the fly

Postural reflex (Learning control circuit (ISO-learning))

Learning control

During learning

Motor control

Body control

Left Leg

Right Leg

Leg control (lateral 5)

Inter-joint control (lateral 2)

Joint control (Spinal 1)


Adaptive walking on different terrains (learning mechanism)

Conclusions

- Sensor-driven neural control = Neural preprocessing unit + Modular neural control unit (modular design)
  - Neural oscillator network (CPG)
  - Velocity regulating networks (spont turning, backward walking)
  - Phase switching network (lateral movements)
- Adaptive reflex neural control (nested-loop design)
  - Biomechanical level (passive walking properties)
  - Spinal reflex level (fast walking)
  - Postural reflex level (adaptive walking)
- Proposed neural control designs can be powerful techniques to better understand and solve sensorimotor coordination problems of many degrees-of-freedom systems.

Thank you for your attention.
See real walking robots at BCCN Göttingen.