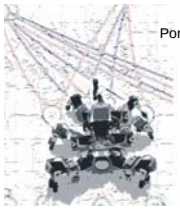
Sensor-Driven Neural Control for Omnidirectional Locomotion and Versatile Reactive Behaviors of Walking Machines



Poramate Manoonpong

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Contents

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A brief overview of walking machine paradigms:

"The idea of walking machines is not new; there has already been, in France, forty odd patents for such applications" (Lucas 1894 [1]) !! 113 years ago

Construction: engineering design, biomimetic robots [2]

One leg | Two legs | Three legs | Four legs | Six legs | Etc.

Control: locomotion control, behavior control

-Engineering control approach (Forward/inverse kinematics (dynamics))
➡-Biomimetic control approach: reflex, central pattern generators (CPGs), high level (brain)

[1] Lucas, E. Huitieme recreation-La machine a marcher. Retreat. Math. 4 (1894), 198-204.
[2] http://www.walking-machines.org/

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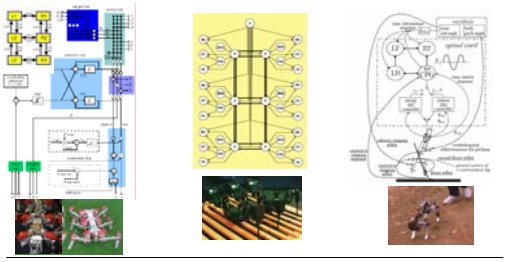
Biomimetic control approach (reflex and CPGs) from walking animals to walking machines

Cruse's model (6 legs)[14] | Beer's model (6 legs) [15] | Kimura's model (4 legs)[16]



Reflexive network No CPG(s) | **CPGs** | **CPGs**

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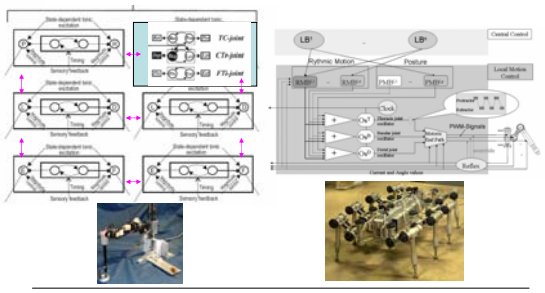
Bueschges' model (single leg control for 6 legs) [17] | Spenneberg & Kirchner's model (8 legs) [18]



CPGs | **CPGs**

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Modular neural control

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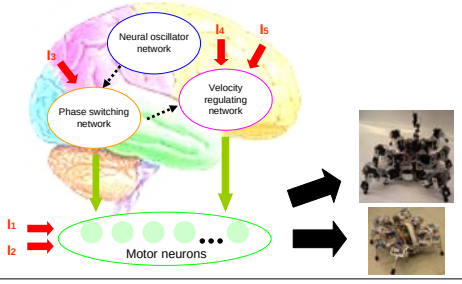
Modular neural control for omnidirectional walking and a self-protective reflex



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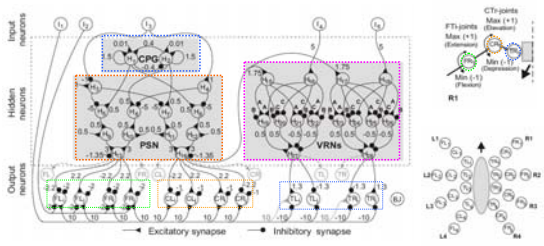
Modular neural network



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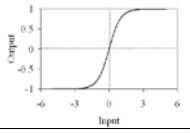
Neural modeling

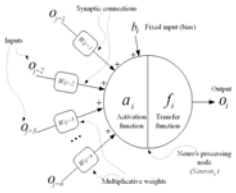
The activation function

$$a_i(t+1) = \sum_{j=1}^{n} w_{ij} o_j(t) + b_i, \quad i = 1, \ldots, n$$

The transfer function

$$f(a_i) = tanh(a_i) = \frac{2}{1+e^{-2a_i}} - 1$$





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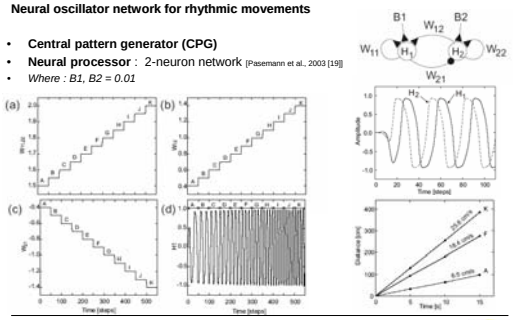
Neural oscillator network for rhythmic movements

- **Central pattern generator (CPG)**
- **Neural processor** : 2-neuron network [Pasemann et al., 2003 [19]]
- *Where : B1, B2 = 0.01*



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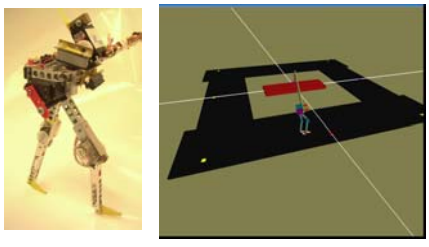
First approach: CPG for basic walking



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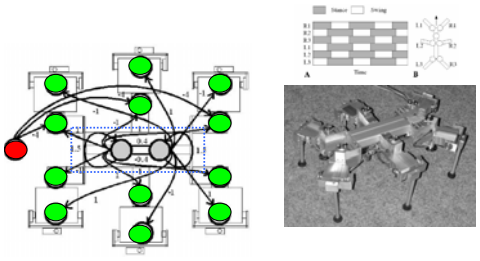
First approach: CPG for basic walking [Fischer et al., 2004 [20]]



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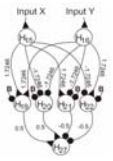
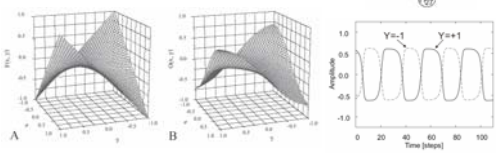
Velocity regulating network (VRN) for spot turning

- **Input signals** : *Input X = the oscillating signal*
  Input Y = sensory signal [1, -1] = I_4 , I_5
- **Neural processor** : Multiplication network [Fischer 2004 [21]]
- *Where : B = -2.48285*





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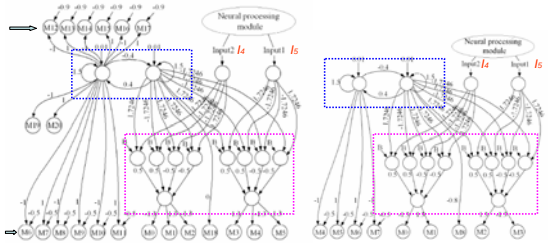
Second approach: CPG + VRNs = forward, backward, turning left and right, and marching movements [Manoonpong et al., [22]]



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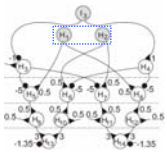
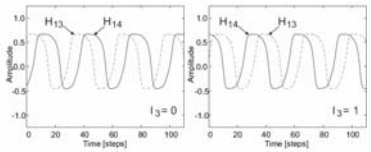
Phase switching network (PSN) for lateral motions

- **Input signal** : I_3
- **Neural processor** : the hand-designed feedforward network *





*Thank Martin Hülse for his technical advise.

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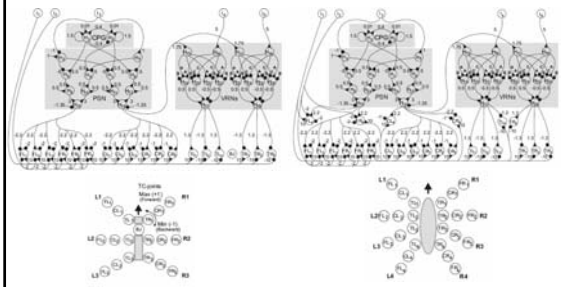
Third approach: CPG + VRNs + PSN = omnidirectional locomotion control



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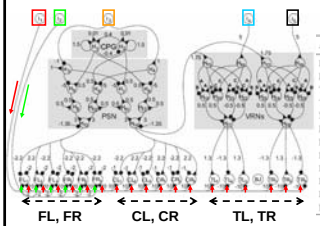
Neural Parameters for Generating Different Walking Patterns



Actions	I_1	I_2	I_3	I_4	I_5
Forward	0	1.0	1, 0	−1.0	−1.0
Backward	0	1.0	1, 0	1.0	1.0
Turn right	0	1.0	1, 0	−1.0	1.0
Turn left	0	1.0	1, 0	1.0	−1.0
Marching	0	1.0	1, 0	0.0	0.0
FDiR	0	0.0	0	−1.0	−1.0
BDiR	0	0.0	0	1.0	1.0
LaR	0	0.0	0	0.0	0.0
FDiL	0	0.0	1	−1.0	−1.0
BDiL	0	0.0	1	1.0	1.0
LaL	0	0.0	1	0.0	0.0
Reflex	1	0.0 ...1.0	1, 0	−1.0 ...1.0	−1.0 ...1.0

At least 12 actions !!

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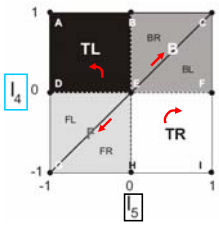
Plot of the input space (I_4, I_5)



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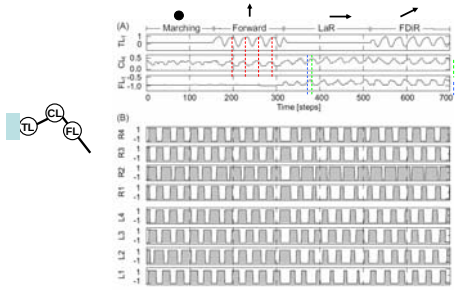
Robot walking experiments



The TC- and CTr-joints are in phase = forward

The FTr-joints of left lead the CTr-joints of left by ¶/2 = LaR, and vice versa for the right side

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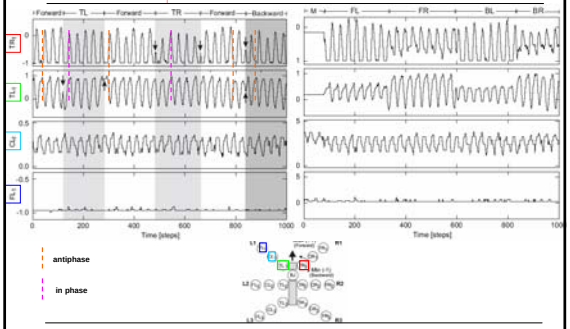

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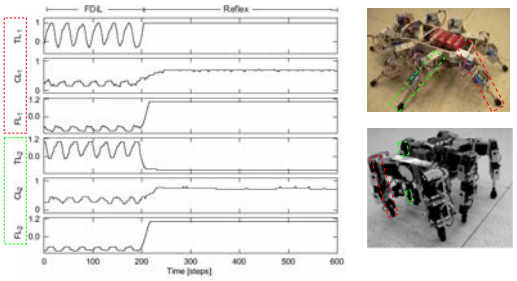
Robot walking experiments



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Robot walking experiments

Simulated walking machines
on
Yet Another Robot Simulator
(YARS)

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Robot walking experiments

Neural Control for
Omnidirectional Walking
of
AMOSWD-06

Modular neural control for
omnidirectional walking
and a reflex behabior
of
the AMOS-WD08

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Neural preprocessing of sensory signals for sensor-driven control

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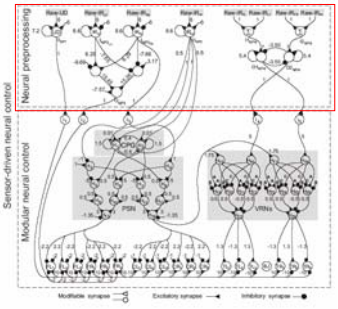

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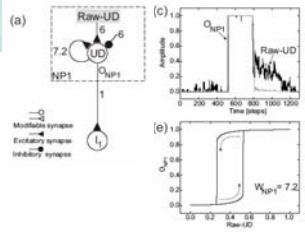
Neural preprocessing of a reflex signal (self-protective reflex behavior)



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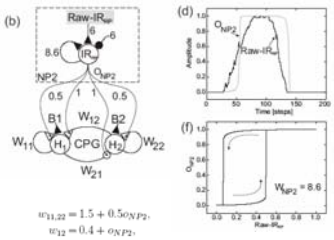
Neural preprocessing of a speed control signal (escape behavior)



$$w_{11,22} = 1.5 + 0.5o_{NP2},$$
$$w_{12} = 0.4 + o_{NP2},$$
$$w_{21} = -0.4 - o_{NP2},$$

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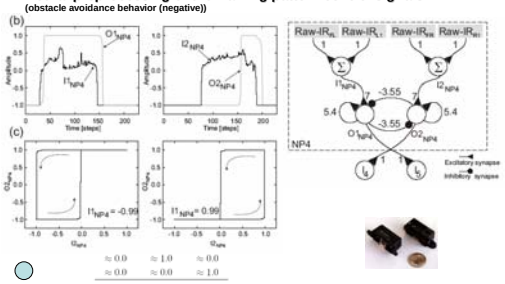
Neural preprocessing of the walking pattern control signals
(obstacle avoidance behavior (negative))



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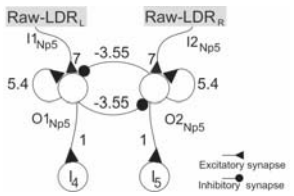
Neural preprocessing of the walking pattern control signals
(phototropism (positive))



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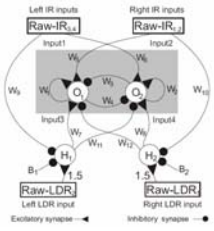
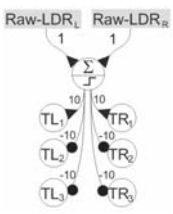
Neural preprocessing of IR and LDR signals (obstacle avoidance and phototropism)





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Sensor-driven behaviors: Reflex, Escape, Obstacle avoidance and phototropism behaviors

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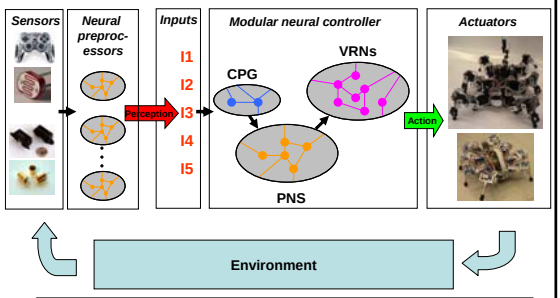
Conclusion



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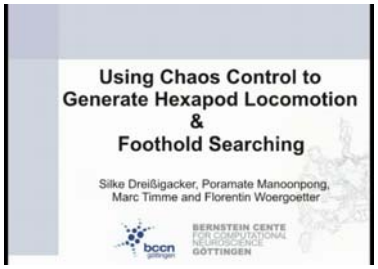
Chaos control for different walking gaits [23]



Schmelcher and Diakonos (SD) method = a tool for the gobal detection of UPOs of a desired period in a chaotic system

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Biologically inspired sensor-driven walking behaviors

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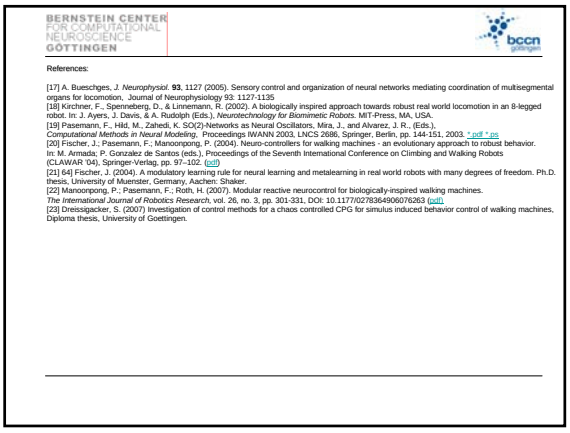

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