Task4.2
Affective Modulation of Embodied Cognition: Transition from Humanoid Crawling to Walking: A Dynamic System View

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University of Skövde
FEEL&WANT Node

Robotics for Development of Cognition

Personal Experience

1. Working Background:

   Research Assistant , Massey e-center, Auckland, New Zealand.

   Job description: Mastication Robot

2. Study and Research Background:

   MSc in Electronic Engineering, HKUST, HK SAR.

   Master´s Project:

   Handwriting robot on the 6-DOF PUMA robotic arm

RobotDoC Training Experience

Conferences:

Conference name	Locations	Date
MC/ESOF Conference	Torino, Italy	01/07/2010-07/07/2010
Epi-Robotics Conference	Orenas Slott, Sweden	05/11/2010-07/11/2010
SweCog Conference	Umea, Orenas Slott, Skovde ,Sweden	06/05/2010-08/05/2010, 03/11/2010-05/11/2010, 12/05/2011-14/05/2011
EuCog Conference	Thessoloniki, Greece	10/04/2011-12/04/2011
FET11 Conference	Budapest, Hungary	03/05/2011-07/05/2011
ICAE Conference	Shanghai, China	10/06/2011-12/06/2011
ICDL&EPIROB Conf	Frankfurt, Germany	24/08/2011-27/08/2011

Courses and Summer Schools

Categories (Course or Summer School)	Location	Date
Emotion and Affect	Skövde Univ	Apr- Oct 2010
Neural Networks	Skövde Univ	Sep-Nov 2010
Info Fusion	Skövde Univ	Sep 2010-Jan 2011
Adaptive Robotics	Skövde Univ	Nov 2010-Jan 2011
iCub Summer School	Sestri Leventi, Italy	July, 2010 July, 2011

Publications:

1. C. Li, R. Lowe, B. Duran and T. Ziemke "Humanoids that Crawl: Comparing Gait Performance of iCub and NAO Using a CPG Architecture," in the Proceedings of IEEE International Conference on Computer Science and Automation Engineering (CSAE), 2011

2. G. Lee, R. Lowe, and T. Ziemke, "Modelling Early Infant Walking: Testing a Generic CPG Architecture on the NAO Humanoid ," in the Proceedings of IEEE Joint Conference on Development and Learning and on Epigenetic Robotics, 2011

As for posters, please see the RobotDoC Website(http://www.robotdoc.org)

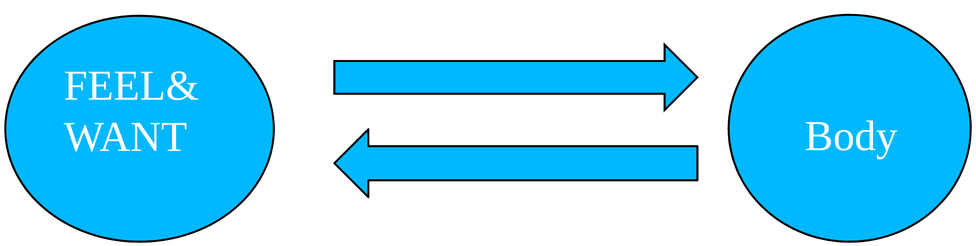
RobotDoC
Training Cooperation

Exchange Program:

Location	Time	Task
University of Zurich	July, 2011	Gait transition of a quadrupedal robot

Supervisors: Robot Lowe and Tom Ziemke (University of Skövde)

External Supervisor: Rolf Pfeifer(University of Zurich)



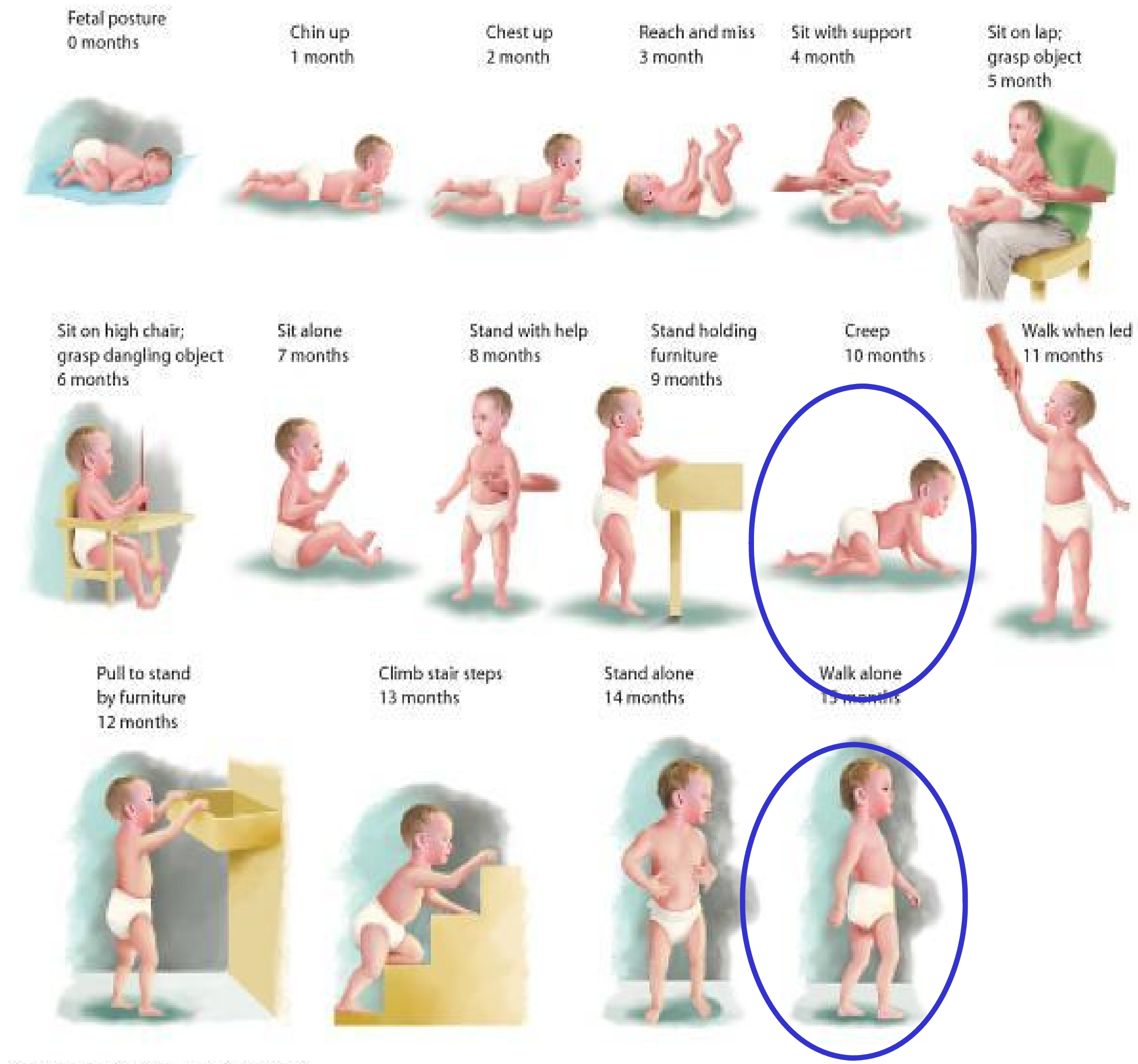
Future Career Plan

Interest in cognition and action on robots with different morphologies → Academic: Postdoc or researcher

Experience on using NAO and iCub humanoids → Industry: Robotics-related companies(Alde-baran, Honda, Volvo, Apple)

Knowledge transferred to my previous jobs → Go back to China or New Zealand

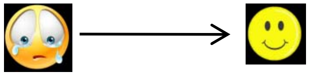
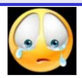
The Role of Cognition and Affect



Based on Shirley, 1931, and Bayley, 1969.

1. The transition depends on two levels:
   a. Sensorimotor level (Posture control and CPGs): bottom-up info
   b. Cognitive level (Dynamic Fields): top-down info
2. The affect role:
   a. Reinforcement learning: eg. Two-level Meta-parameter learning
   b. An interactive learning : eg. Parental interaction(Allan Schore, 1999)

My Schedule and Future Work

Time	Main Planned work	Expected Results	Finished?
March – Sep, 2010	Literature Review(CPGs, Reinforcement learning, DFT, Child Development, emotion, etc.)	Have an explicit plan on my PhD to-do list	
Oct- Dec, 2010	Implementation of Crawling module on the NAO robot	A comparison between NAO and iCub	
Jan-March, 2011	Understanding infant walking and model it	A minimalistic model on infant walking	
Apr- Oct, 2011	An inverse kinematics model based on control parameters	Given five control parameter, it can generate joint value for each joint	
Nov-Dec, 2011	Transition fields simulation and C++ coding	A genetic landscape 3D module	
Jan- March, 2012	Finish the GUI of fields	GUI	
March – May, 2012.	Combine Fields with IK module and do the posture transition from quadrupedal to bipedal	Implementation on the real robot	
June – Aug, 2012	Combined with CPG Architecture	Implementation on the real robot	

Thank you very much for your attention!

Publications:

1. C. Li, R. Lowe, B. Duran and T. Ziemke "Humanoids that Crawl: Comparing Gait Performance of iCub and NAO Using a CPG Architecture," in the Proceedings of IEEE International Conference on Computer Science and Automation Engineering (CSAE), 2011
2. G. Lee, R. Lowe, and T. Ziemke, "Modelling Early Infant Walking: Testing a Generic CPG Architecture on the NAO Humanoid ," in the Proceedings of IEEE Joint Conference on Development and Learning and on Epigenetic Robotics, 2011

References:

1. Allan. N Schore, Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development, Hillsdale, New Jersey, 1994
2. Esther Thelen and Linda. B. Smith, A Dynamic Systems Approach to Development of Cognition and Action, MIT Press,1994

Presentation Breakdown

1. Introduction to crawling to walking transition

- Neural-scientific model(McGraw,1932,1940,1945 && Zelazo 1984)
- Dynamic system model (Thelen , 1998)
- Robotic model (Aoi, 2010 and Asa 2004)

2. Affect plays a role in coordination of the infant motor capabilities

3.Proposed model

- The Architecture of proposed model (CPG architecture which integrates information from vestibular(posture), proprioceptors(muscle spindles) and context (interaction))
- CPG model (crawling and minimalistic walking model)

Introduction

Neural-scientific model(McGraw, 1932,1940,1945):
Reflex stepping, static phase, a transition phase, deliberate stepping, independent stepping, toe-heel progression, integrated walking.

It is caused by the immature cortical part of the brain becomes more dominant from an undeveloped state and suppresses the excitation of the sub-cortical part.

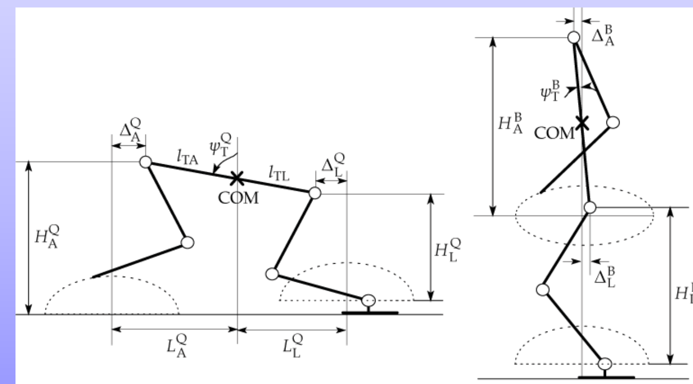
Robotic Model (Aoi , 2010 and Asa, 2004):

Proprioceptive information integration:

Inverse kinematics and spring-like ground

CPGs: Oscillator-driven end effector trajectory generator

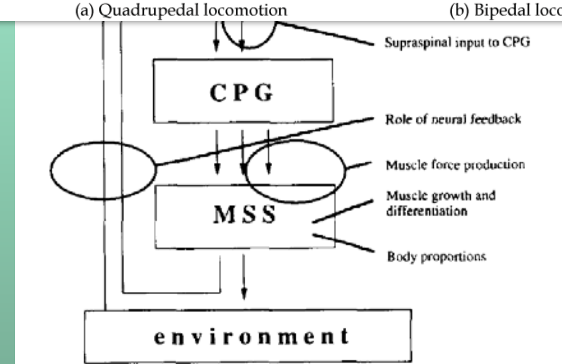
Posture: Control parameters



(a) Quadrupedal locomotion (b) Bipedal locomotion

CPGs could be generic models for locomotion development but are not only causes.

The stable walking behaviors should emerge from a function of their experience with walking on the Visual, vestibular and proprioceptive information.



The Role of Affect and Emotion

A Reinforcement learning problem:

a. Rewards play an important role on different synergistical aspects(where do the rewards come from):

1. Neural-anatomic:

- From dopamine centers(e.g. VTA, substantia nigra)

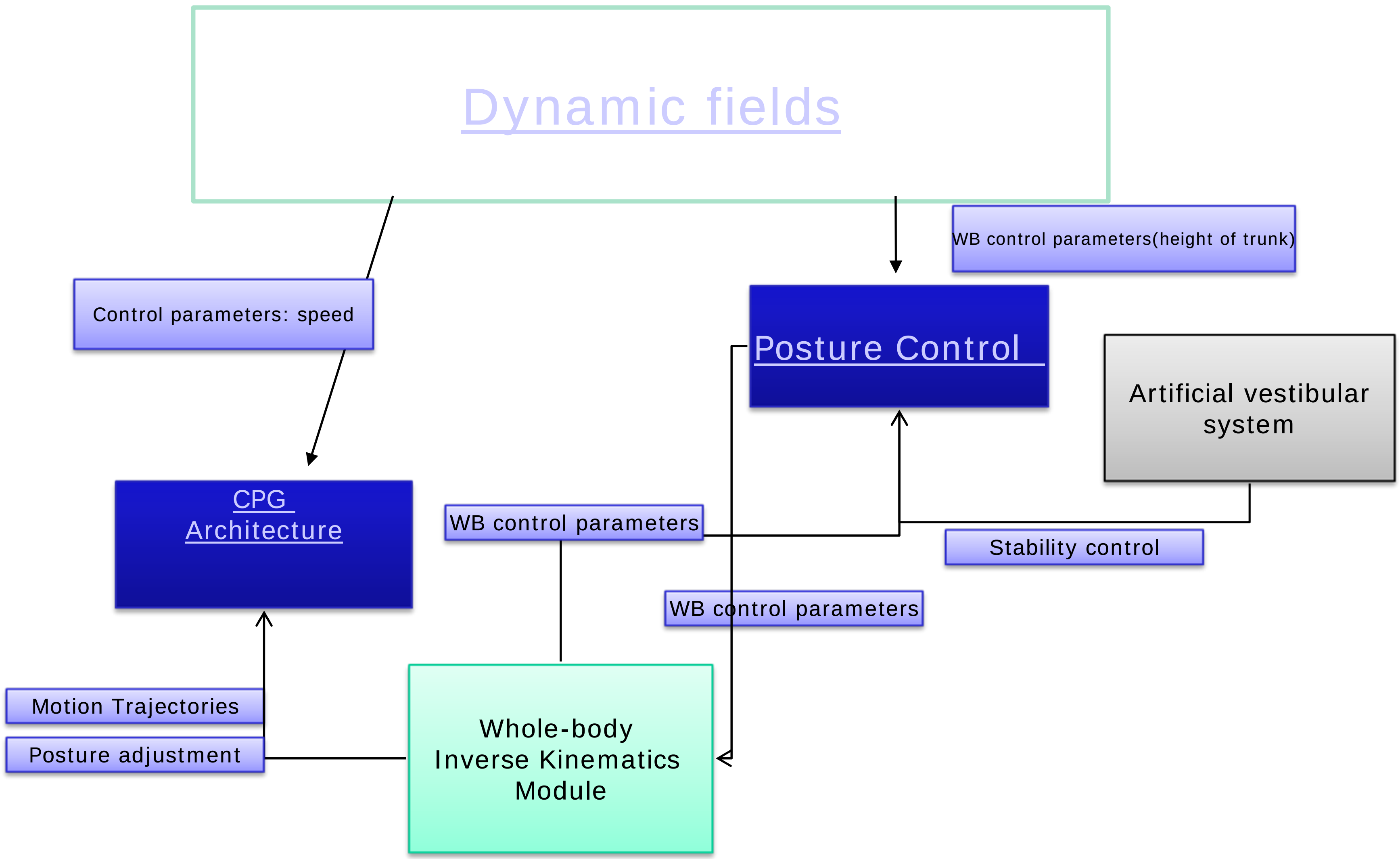
1. Behavioral:

- From gesture(posture)---- e.g. vestibular system--basal ganglion feedback loop , Mori's Japanese monkey(Mori.F, 2001)
- From interaction (context) --- e.g. infant and mother attachment which indicates emotion system(Allan Schore, 1994)
- From proprioceptive signals: e.g. speed, kinematics, dynamics

b. Rewards can be used to develop and improve locomotion on different levels

- Neuronal Connectivity e.g actor-critic architecture (Nakamura, 2007)
- States / Muscle synergies e.g On-line learning CPG model (Ijspeert, 2009)
- Topology of the locomotor DOF / Graph e.g Benrstein's DOF Assumptions (Bernstein, 1967), My own CPG Models

Proposed Model for Crawling to Walking Transition

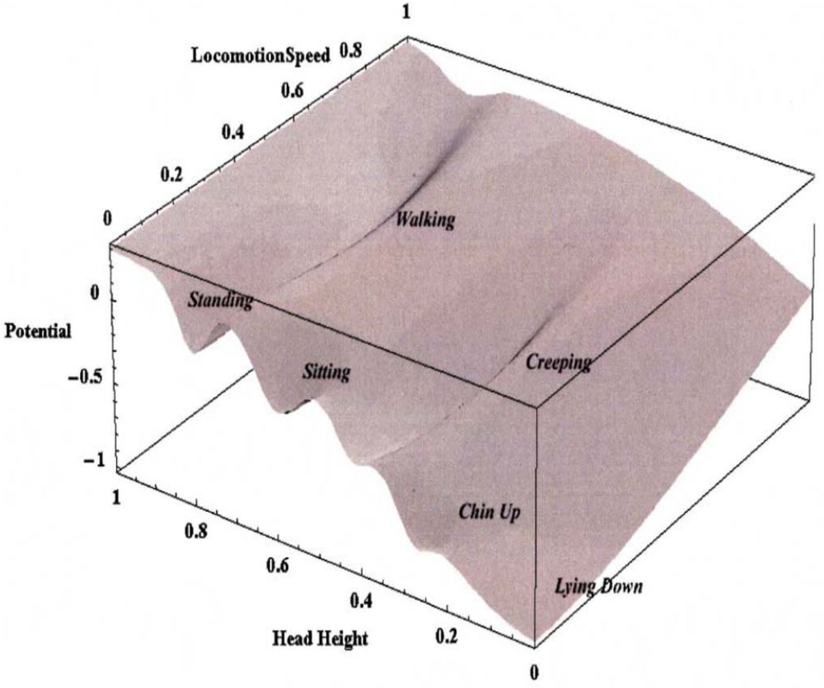


Dynamic fields(Thelen,1994)

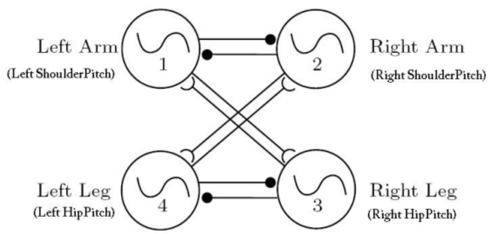
Advantages of dynamic fields:

1. Bridge between genotype and phenotype
2. Capabilities to do smooth gait transitions
3. Describe locomotion abilities in a 3D space
4. Integrate proprioception and vestibular system feedback in a 3D space.

The fields here work as a high-level control centers



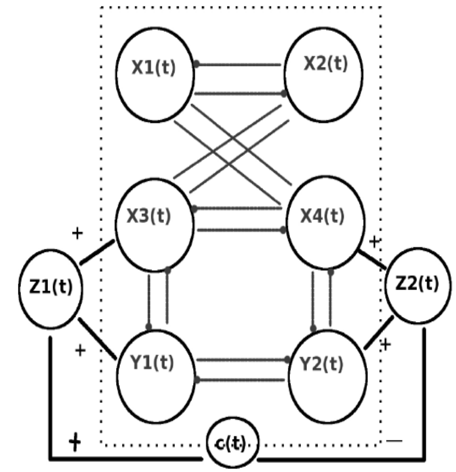
Minimalistic CPG models

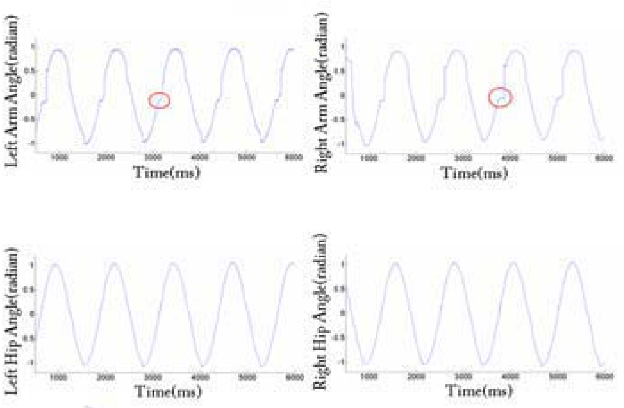


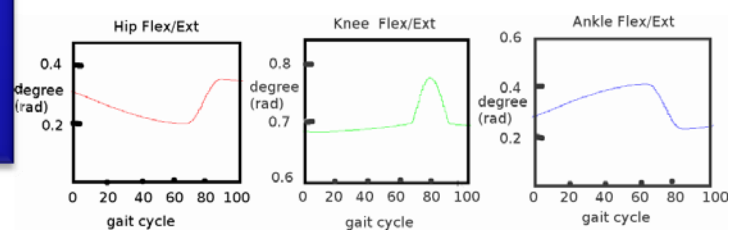
It shows dynamics development on three levels:

1. Connectivity
2. Neuron states
3. Neuron graph

These three developmental changes are considered to be most important in locomotion development (Vaal, 1995)

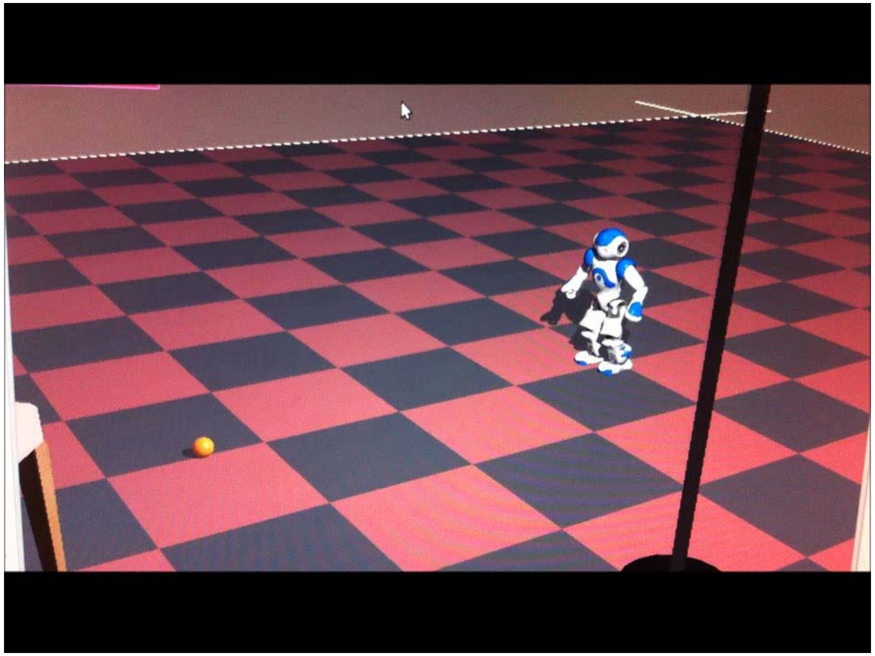






Crawling NAO

Infant walking and simple transition



Complicated CPG models

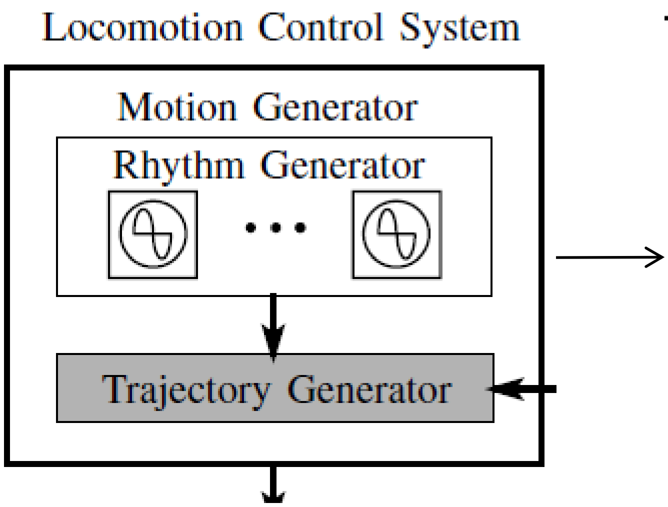
Actor-Critic architecture(linking rewarding to connectionism of supraspinal CPGs).

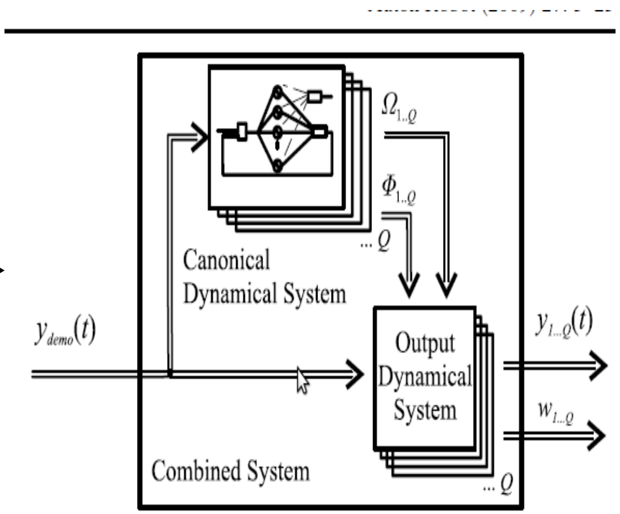
Drawbacks of traditional approach:

- No information from proprioceptive system (biomechanical)
- Time-consuming

DSA model:

On-line learning which involves proprioceptive system and interaction with the context (Aoi, 2010 and Ijspeert, 2009)



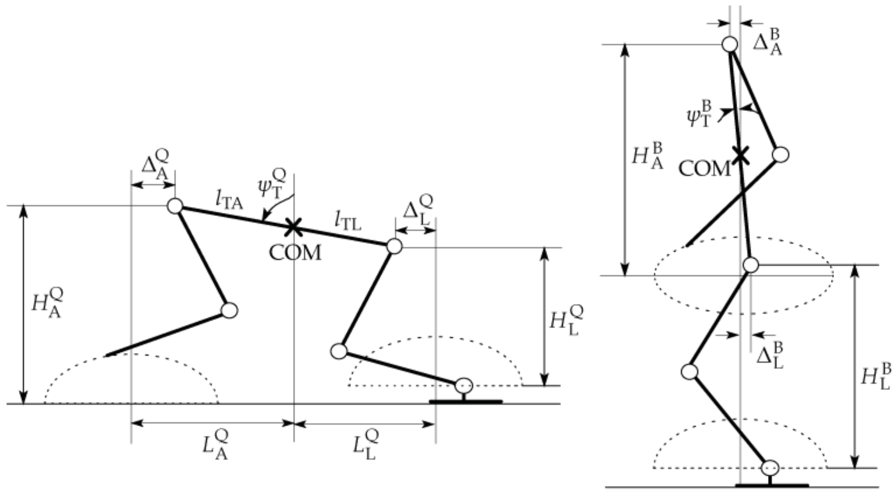


Posture Control (Aoi, 2008)

By using inverse kinematic model controlled by crucial control parameters:

control parameters:

1. Height of rear extreme point of the trunk (REPT)
2. Height of front extreme point of the trunk (FEPT)
3. Angle of the trunk
4. Distance between REPT and center of AEP(anterior extreme position) and PEP(posterior extreme position)
5. Distance between FEPT and center of AEP and PEP



(a) Quadrupedal locomotion (b) Bipedal locomotion

Conclusions and Future work

1. Benefit and drawbacks of using NAO for crawling and walking

Benefit:

a. a very typical humanoid
b. It has a complete architecture of software(ROS+Naoqi) and hardware which are feasible to implement these two behaviors.

Drawback:

a. Position control robot

2. Advantage of the involvement of the affect:

Reinforcement learning is a general approach which can resolve two-level learning problems.

References:

1. Allan. N Schore, Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development, Hillsdale, New Jersey, 1994
2. MacGraw, R.B. From reflex to muscular control in the assumption of an erect posture and ambulation in the human infant. Child Develoment, 3, 191-297
3. Shinya Aoi et al, Experimental Verification of Gait Transition from Quadrupedal to Bipedal Locomotion of an Oscillator-driven Biped Robot, 2008 IEEERSJ International Conference on Intelligent Robots and Systems (2008)
4. Kenji Asa, et al. Behavior transition between biped and quadruped walking by using bifurcation , in the Proceedings of 9th International Conference on Intelligent Autonomous Systems (IAS-9)
5. Esther Thelen and Linda. B. Smith, A Dynamic Systems Approach to Development of Cognition and Action, MIT Press,1994
6. Mori.F, Bipedal locomotion by the normally quadrupedal Japanese monkey, M. Fuscata: strategies for obstacle clearance and recovery from stumbling. Acta Physiol Pharmacol Bulg, 2001;26(3):147-50.
7. Yutaka Nakamura, Takeshi Mori, Masa-aki Sato and Shin Ishii, Reinforcement Learning for a Biped Robot Based on a CPG-Actor-Critic Method, *Neural Networks*, 2007, 20(6), pp.723-735
8. Bernstein, N., 1967. Coordination and regulation of movements. New York: Pergamon Press.
9. Vaal J. Modelling the early development of bipedal locomotion: A multidisciplinary approach, Human Movement Science, Volume 14, Number 4, November 1995 , pp. 609-636(28)
10. Gams et al. On-line learning and modulation of periodic moveme , Autonomous Robots, vol. 27, num. 1, p. 3--23, 2009.

Questions slides:

There is no essentials, there is only performance in a specifying context.

About the whole-body inverse kinematics:

$J(\theta) = T(P)$ plus a solution estimate policy

Dynamic fields questions and Reinforcement learning

Cognitive level:

Temporal learning process

Policy: π

Rewards : vestibular system

Sensorimotor level:

$$
\begin{aligned}
\Delta_A(\xi_1, \xi_2) &= \Delta_A^Q - \{l_{TA} \sin \psi_T(\xi_1, \xi_2) + \Delta_A^Q\}\xi_1 \\
\Delta_L(\xi_1, \xi_2) &= \Delta_L^Q - \{l_{TL} \sin \psi_T(\xi_1, \xi_2) + \Delta_L^Q\}\xi_1 \\
H_A(\xi_1, \xi_2) &= H_A^Q + (H_A^B - H_A^Q)\xi_2 \\
H_L(\xi_1, \xi_2) &= H_L^Q + (H_L^B - H_L^Q)\xi_2 \\
\psi_T(\xi_1, \xi_2) &= \psi_T^Q + (\psi_T^B - \psi_T^Q)\xi_2
\end{aligned} \qquad (6)
$$

This aims to use parameters ξ_1 and ξ_2 to change the distance between the foot and hand trajectories and the posture of the trunk, respectively. Using this controller, gait transition is achieved by simply changing introduced parameters (ξ_1, ξ_2) from (0, 0) to (1, 1), as shown in Fig. 5.