

Chapter 5

Development: From Locomotion to Cognition

**How the Body Shapes the Way We Think
A New View of Intelligence**

Rolf Pfeifer and Josh Bongard

Introduction

- Turing test
 - “Can machines think?”
 - A test for intelligence
 - Capacity to imitate a human (imitation game)
- Developmental approach
 - Initial system
 - Training the system by means of an educational process
 - Developmental robotics (embodied systems)
 - Motivation, framework for doing so
 - Symbol grounding problem
 - Case study: **Locomotion**

Motivation

- Simple to complex (Turing's point)
 - **Body** and **Brain** both changes
- Time scale for intelligence behavior
 - Here and now
 - **Ontogenetic (life time -DA capitalize on this)**
 - Phylogenetic (evolution)
- Learning
 - Ability is a measure of intelligence
 - But mostly used in disembodied systems
 - ANN

Motivation...

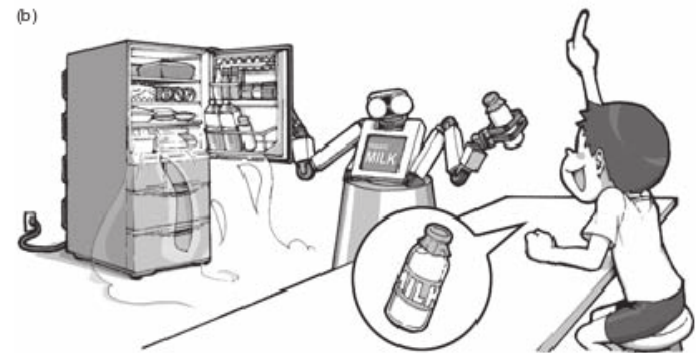
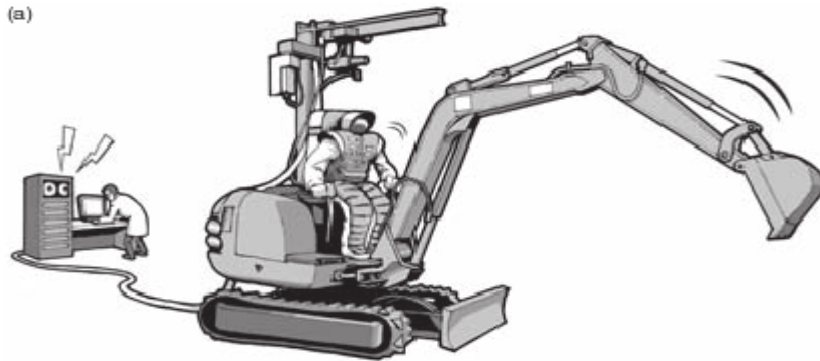
- Potential solution to symbol grounding problem
 - How do agents acquire meaning???
- Synthetic methodology
 - Robots as model of development
 - Cognitive abilities
 - Interactions, environments and people, robots around
- **Desire to create a robot that can grow**
 - Babybot (G. Metta)
 - Infanoid (H. Kozima)
 - Gaining skills rather than physical growth

Developmental Robot Design

- Complex dynamics can be incorporated in attractor states
- Search of discrete symbols in dynamical systems
- Why humonoids?
 - New technologies
 - Sensors
 - Batteries
 - Miniaturization
 - Control algorithms
 - New conceptual directions by looking at difficulties (passive legs, artificial muscles, etc)

Robot Design ...

- No need to change the environment
(typing, piano playing, play golf, driving a car, etc)



Robot Design ...

- **Problem with Humanoid robotics**
 - People try to attribute human like properties (language, pain or pleasure)
 - “Anthropomorphization, the incurable disease”
David McFarland
 - In appropriate associations for robot's actual abilities
 - **Still far from approaching human-level intelligence**
- **Humanoids not be the only tool**
 - eg. Four legged robot puppy

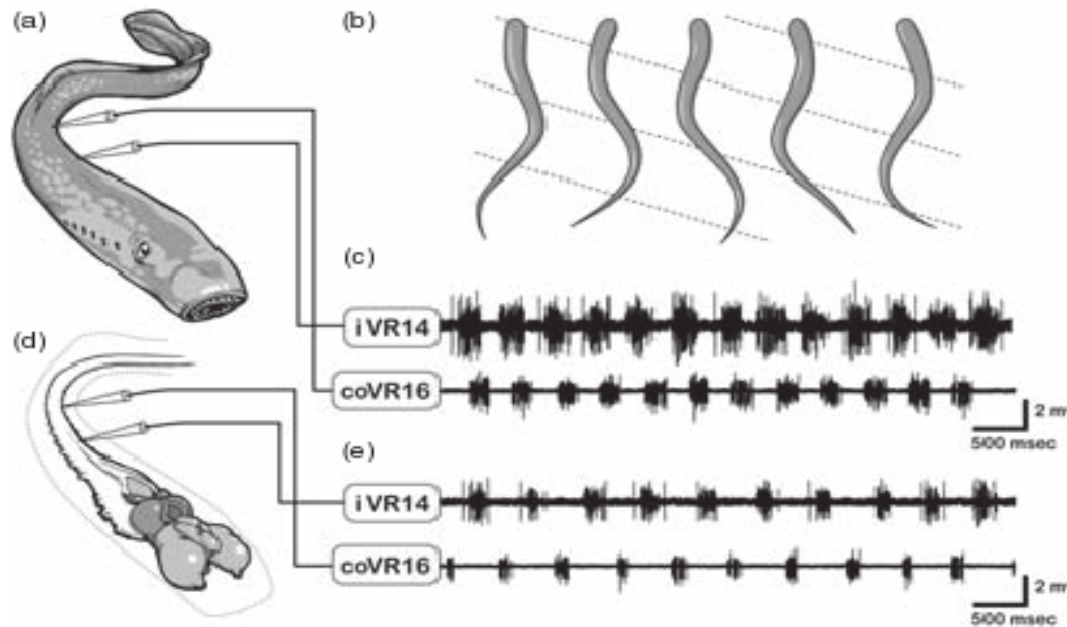
A Case Study- Locomotion

- **Puppy robot**
- **Different gaits**
 - Walking, trotting, racking, cantering and galloping
 - Attractor States (AS) of the combined
 - physical & neural system
 - AS is a result of the interaction with the environment
- **Gaits as Attractors?**
 - Clearly and discretely identifiable
 - Control suitable in particular phase (eg. Stance)
 - Behavior segmentation (control point – stance phase)
 - Symbolic representation, Discretization

A Case Study ...

- **Gaits as Attractors ...**

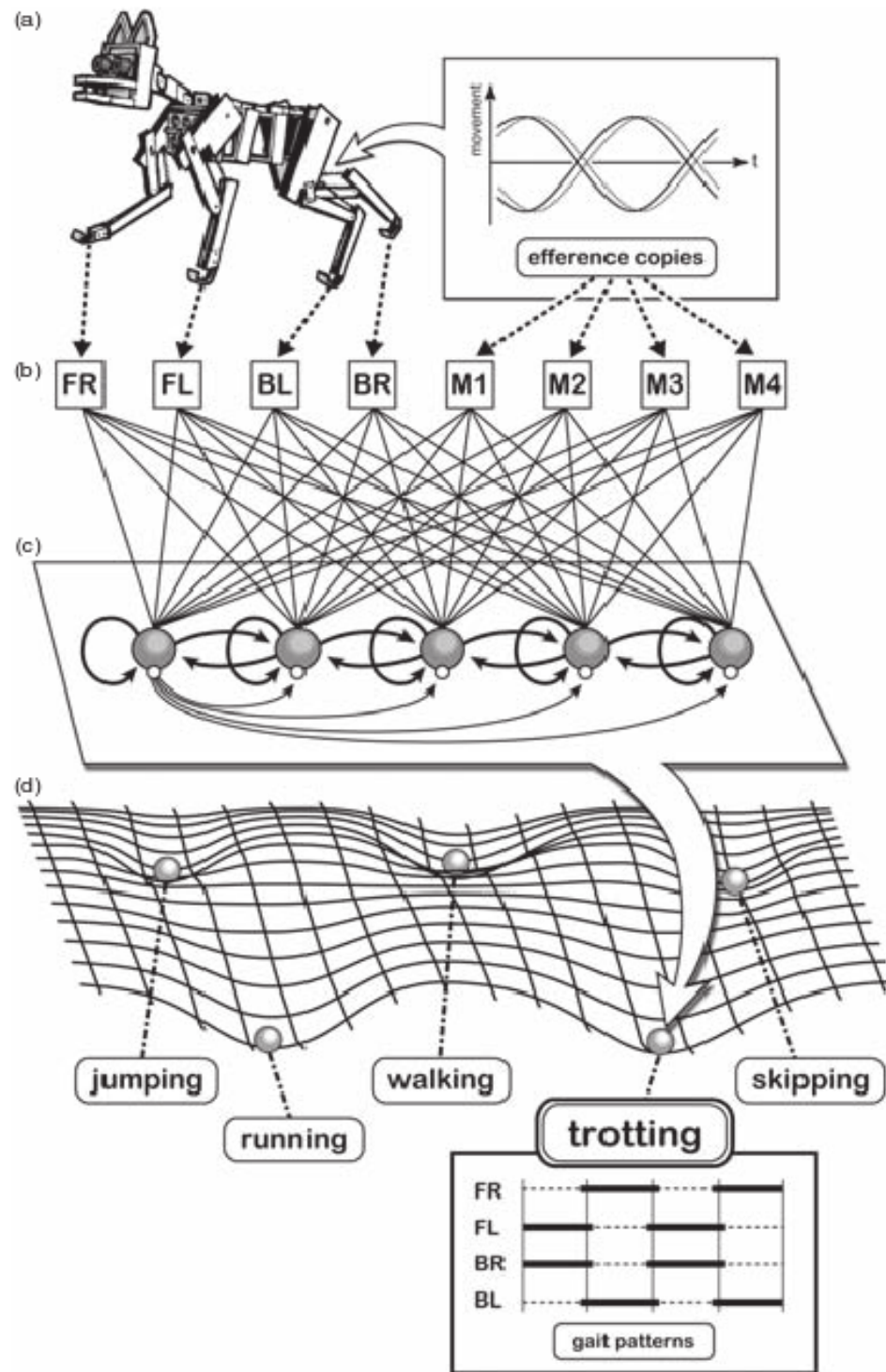
- Dynamics of the Neural & the Body have to be in tune
- Both systems have evolved together



- **Body shapes the brain**
 - **Brain shapes the body**
 - **Brain-Body mutual coupling**
- (Sten Grillner at KI)

From Gait patterns to Body Image to Cognition

- **Body image**--- Neural structures to guide movements and to predict sensory stimulation
- **Repetitive Patterns**
 - Networks of neurons
 - Recurrent connections (short term memory)
 - Biological networks are dealing with the environmental changes but ANN not



Body image ...

- Improvements
 - Add a “watcher” network
 - Transitions between attractor states may trigger state transitions in the “watcher” NW
 - Symbol processing
- Basic body image should be extended ...
 - Notion of the geometry of the body
 - Shapes of the limbs
 - Sensor positions
 - Knowledge about the physiology

Symbol Grounding Problem

- **Getting the meaning by itself**
- *“The semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads” by Stevan Harned*
- Association of pattern of neural stimulation to symbols (actions)
- Important: Need to take human observer out
- System is focused to react with the real world (Autonomous)
- **Robot itself must have rich natural dynamics when it reacts with the environment**