Bernstein Center for Computational Neuroscience Göttingen

BCCN

Biologically-Inspired Mobile Robot Design: Towards Embodiment Systems

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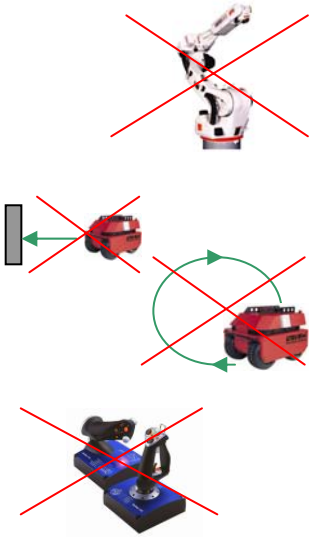
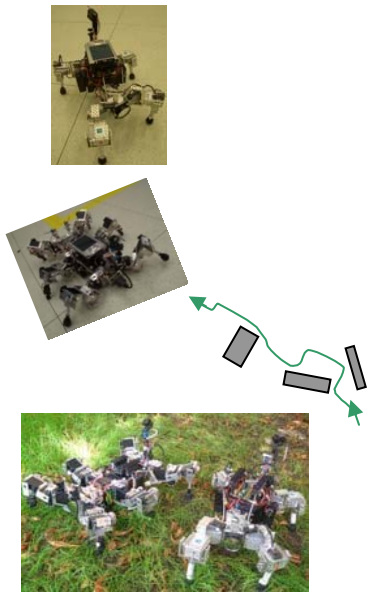
E.g. “What is attractive robotic systems nowadays (at least for me)?”

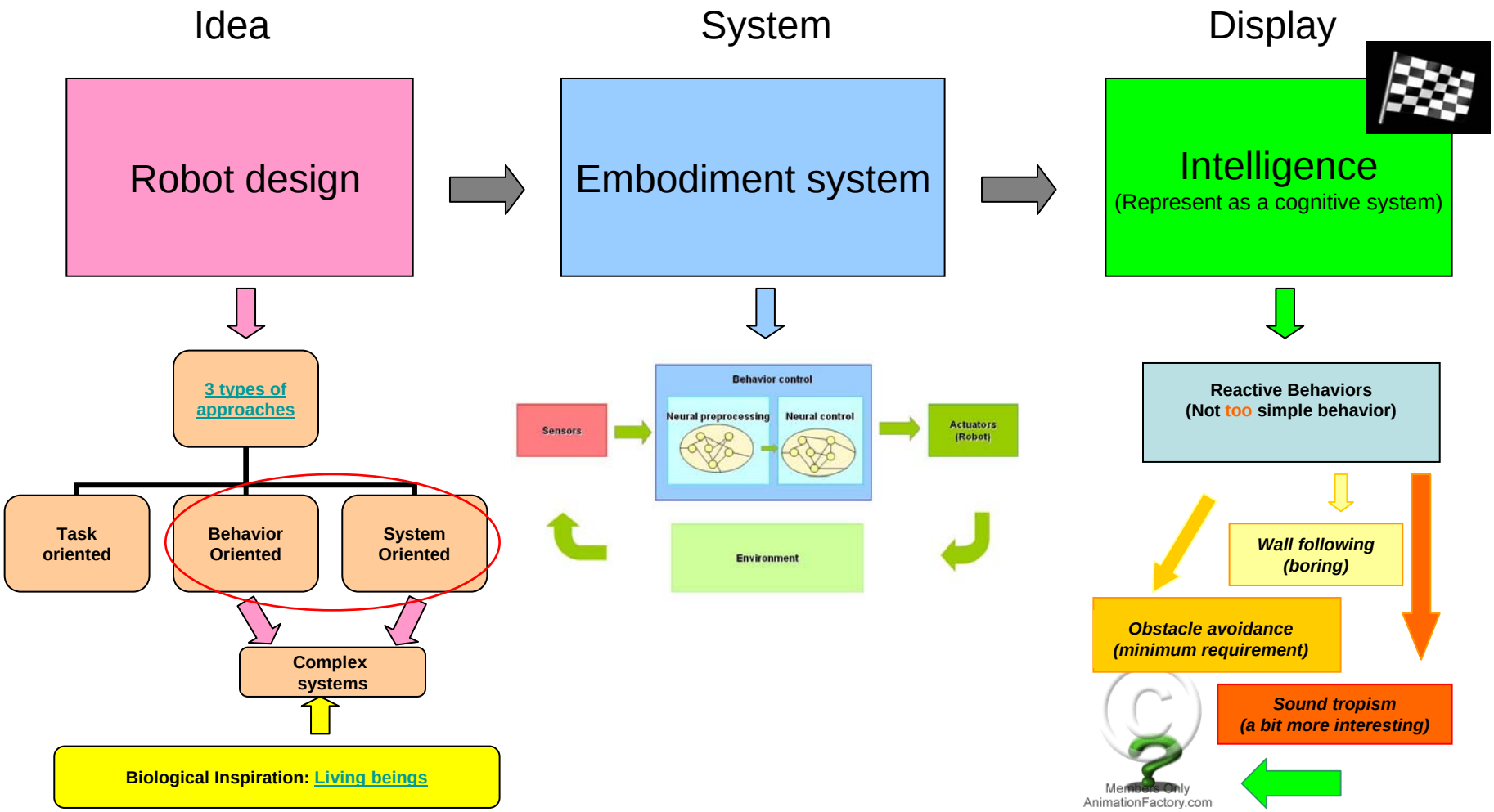


- Mobile robots
- Intelligent
- Autonomous



“***Autonomous Intelligent Mobile Robots***”

Overview


Idea
System
Display
Robot design
Embodiment system
Intelligence
(Represent as a cognitive system)
3 types of approaches
Task oriented
Behavior Oriented
System Oriented
Complex systems
Biological Inspiration: Living beings
Behavior control
Sensors
Neural preprocessing
Neural control
Actuators (Robot)
Environment
Reactive Behaviors
(Not too simple behavior)
Wall following (boring)
Obstacle avoidance (minimum requirement)
Sound tropism (a bit more interesting)
Members Only
AnimationFactory.com

Three approaches for robot design

Task-oriented approach: Designing robots depending on tasks (predefined tasks), e.g. manipulators

Behavior-oriented approach: Designing robots depending on typical movements that can be recognized as behavior (the indirect result of behavior performance may be a specific task and the programming level is higher, more complex than task-oriented approach), e.g. reactive walking machines

System-oriented approach: Designing robots without any particular purpose (i.e. it is able to generate behaviors leading to a satisfactory performance of varied tasks), e.g. humanoid robots

Brief history of Embodiment concept

Embodiment concept has been used in cognitive science and AI lecture since the mid-1980s

In terms of

- Embodied mind (e.g. Lakoff & Johnson 1999; Varela et al. 1991)
- Embodied intelligence (e.g. Brooks 1991)
- Embodied action (e.g. Varela et al. 1991)
- Embodied cognition (e.g. Clark 1997)
- Embodied AI (e.g. Franklin 1997)
- Embodied cognitive science (e.g. Clark 1999; Pfeifer & Scheier 1999)
- And so on …

What are embodiment systems ? And Why ?

[Riegler A. 2002] What:

They exist structural coupling; e.g. Agent-Environment interaction, (environment = objects, another agents and so on). A-E can represents as *Reactive behavior* or *Reflexive Locomotion*

They should synchronize to their environment ; i.e. the outside world can influence the behavior of agent (*situatedness*)

They can be physical body with in the real world or simulated body with in the virtual world; the system must have the body (sensor-brain-actuators)

They have to acquire the ability for adaptability or surviving with in the environment where they are embodied; i.e. they react with the environment without predefine (reactive control)

[Brooks R. 1991] Why:

Environment is part of the cognitive system

It is important to let robots explore and sense their dynamic world. As a result, they become intelligence; i.e.

" *We must incrementally build up the capabilities of intelligent systems (embodiment). At each step of the way it is only necessary to build one small piece and interface it to an existing, working, complete intelligence.*

Embodiment systems

[Duffy B.R. & Joue G. G. 2000] Why:

Embodiment is an inherent property of an agent that exhibits intelligent behavior

In order to achieve cognitive capabilities or a degree of intelligence in an agent , it has to interact with the environment. (Embodiment)

Embodiments should be able to “survive (adapt, learn, develop) ” in their environment

Embodiment systems

What are kind of body is considered to be capable of embodied cognition ?

[Ziemke T. 2002] Six different notions of embodiment:

-Structural coupling : agent-environment interaction

-Historical embodiment : history of agent-environment interaction which also effects to cognitive systems (e.g. evolutionary, learning by performing)

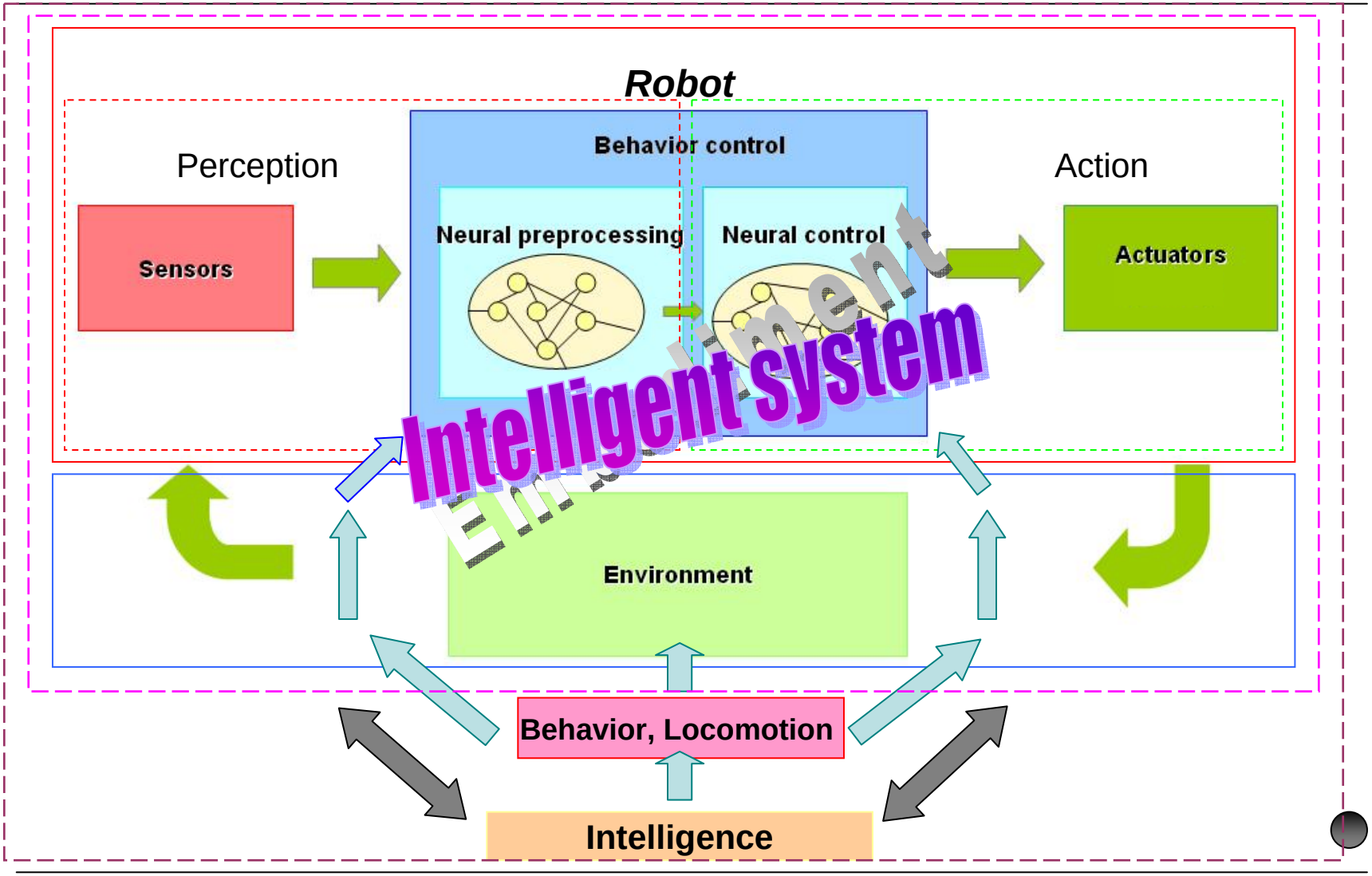
-Physical embodiment : embodied systems need a physical body (sensors+actuators) "*but computer programming can become embodiment if they are the result of self-organization rather than explicit design*"

-Organismoid embodiment (organism-like body) : physical bodied having the same or similar form and sensorimotor functionality in some degree as "*living bodies*"(Khepera robot for cricket model, Cog humanoid robot)

-Organismic embodiment : living bodies able to perform self-organization (e.g. self-repairing)

-Social embodiment : state of body (e.g. postures) arise during social interaction (e.g. swarm robot)

Embodiment systems



Why Living beings?

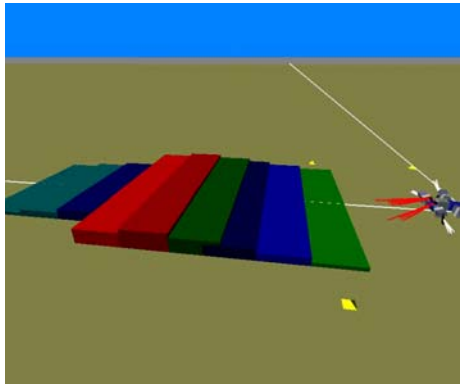
Because: [Coiffet P. 2005]

- They are alive; *i.e. they have the ability to survive and adapt to the environment*
- They have several interesting structure (*e.g. legs, arms, trunk*) and behavior
- They are variety, *e.g. human beings, animals, bacterium*
- They are sensory-motor systems
- They can interact with the environment and the others; *i.e. response to stimuli*
- They have evolution, *e.g. they can develop their ability or even their species*
- They are autonomy
- They are unity, *i.e. body and brain*
- and so on…….

From these points, *they are an excellent inspirational source for designing robots (sensor-motor systems) that perform autonomous (reactive) behaviors*

Additional remarks:

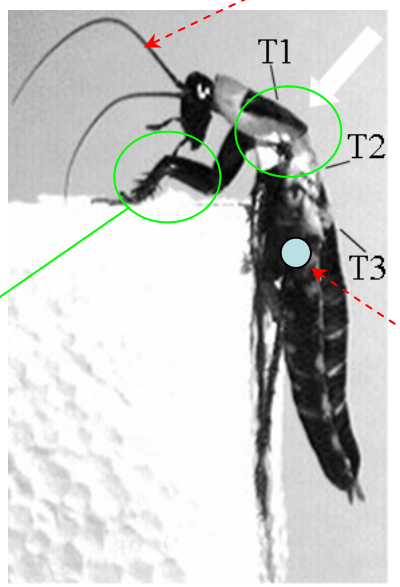
- The agent body defines the kind of interactions with its environment
- The structure of the agent will define the limitation of an environment where it can or cannot proceed
- It even plays an important role in the design of a neural motor control
- A simple body may limit the interest of the behaviors that it can present and it may obstruct the creature from formulating an effective neural motor control for a complex system
- To achieve this potential, agents having morphologies similar to walking animals are presented, here.

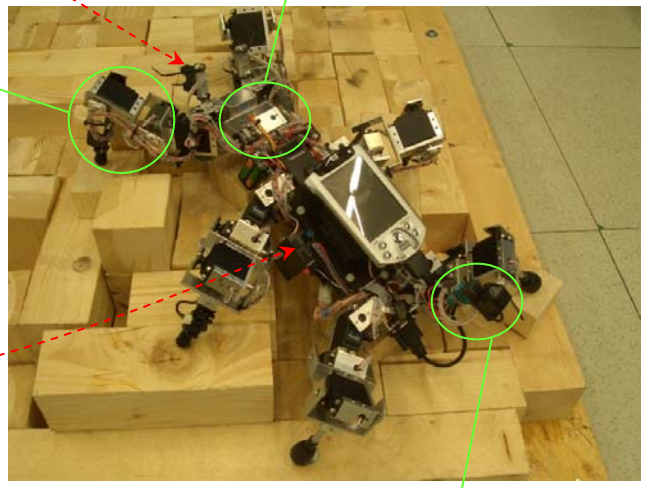


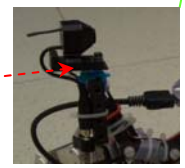
Biologically-Inspired Reactive Walking Machines (6 legs)

From Animals

To AMOSWD-06

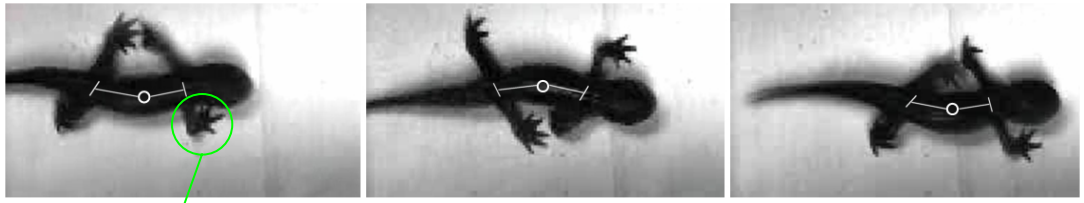


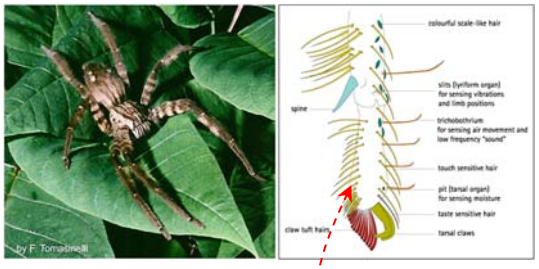




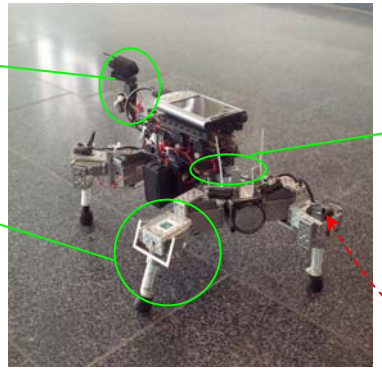
Biologically-Inspired Reactive Walking Machines (4 legs)

From Animals



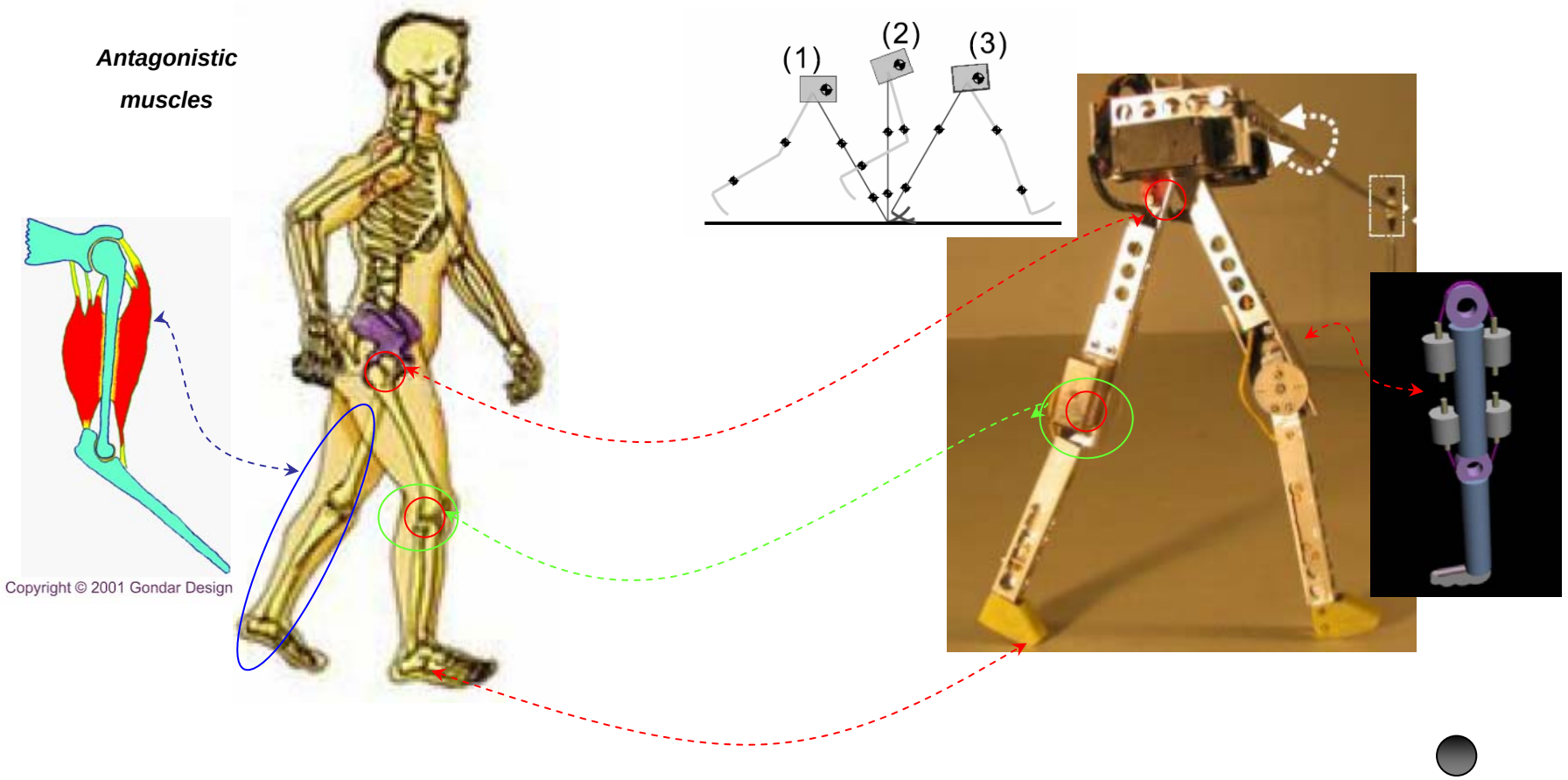


To AMOSWD-02



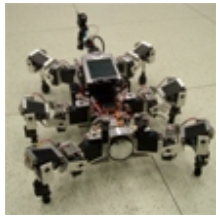
Runbot (2D Biped walking robot), (2 legs)

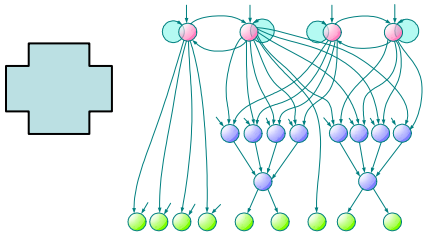
From Human morphology → **To Runbot**



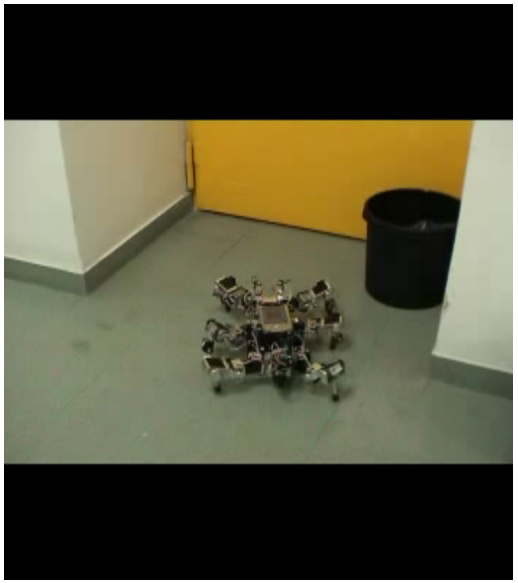
Are they “Embodiments” ?

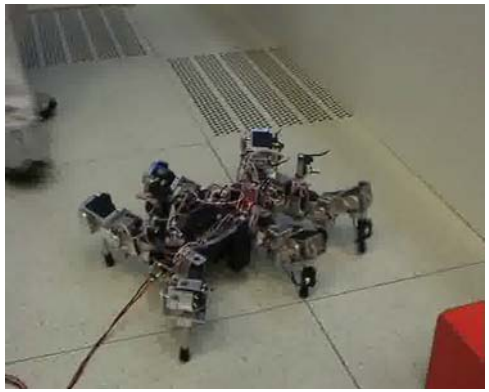
Biologically-Inspired Reactive Walking Machines

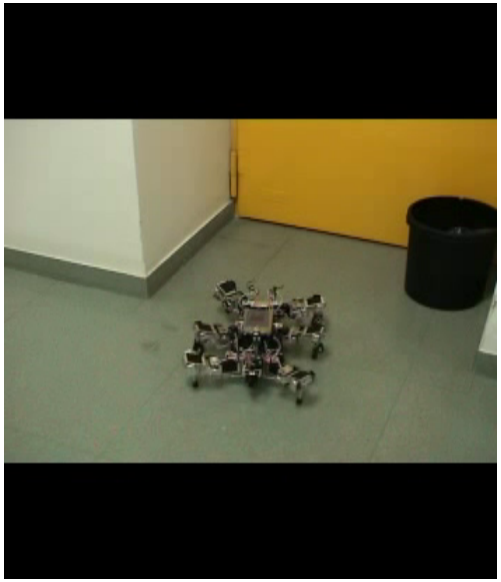




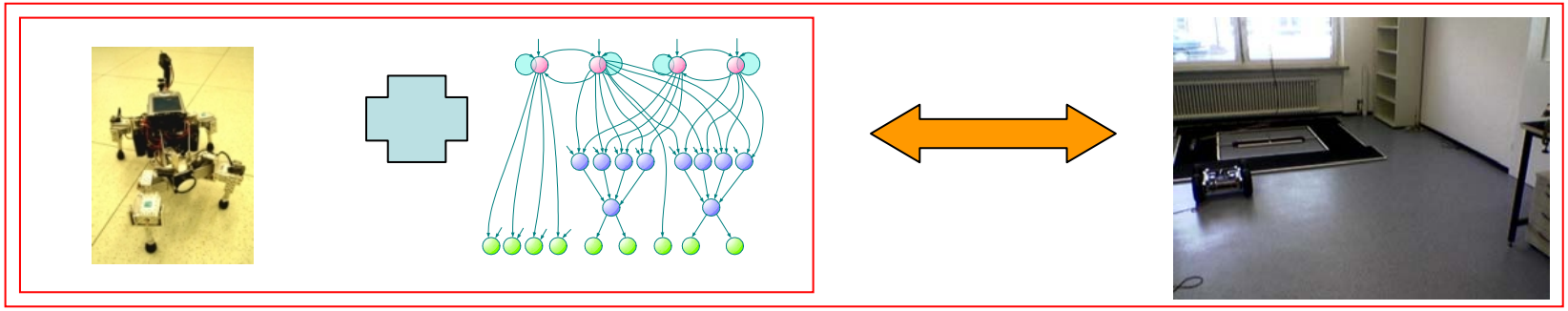
Reactive behavior



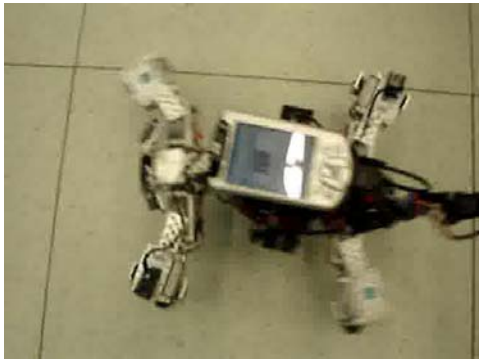




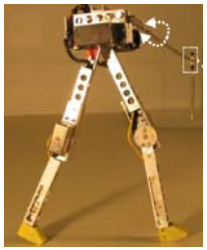
Biologically-Inspired Reactive Walking Machines

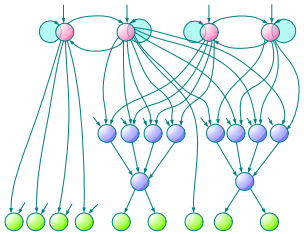


Reactive behaviors



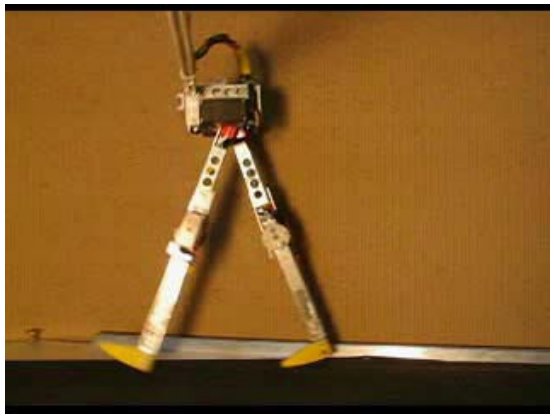
Biologically-Inspired Reactive Walking Machines

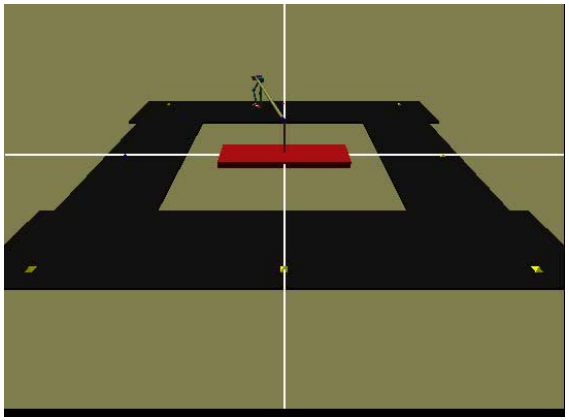




Reflexive control

CPG control





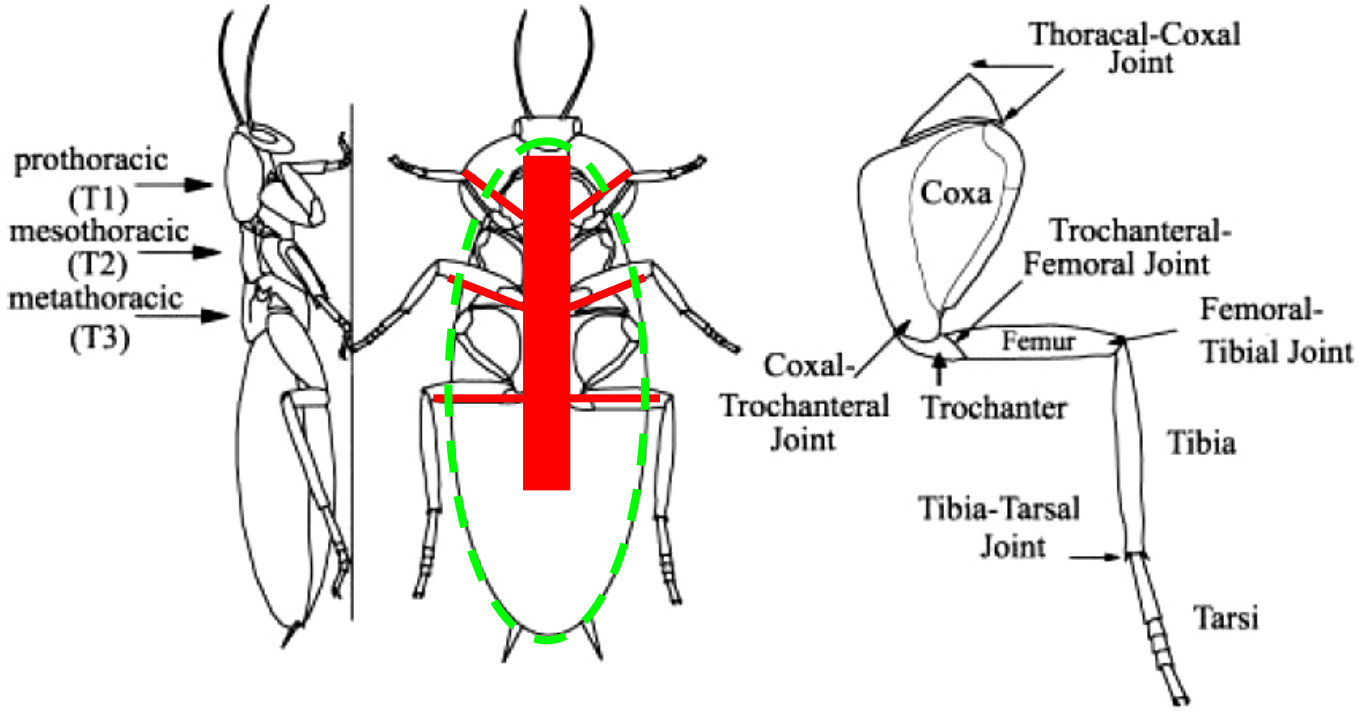
Reactive Behavior Control

Locomotion control

Biologically inspired reactive behaviors: Intelligent system


Thank You

Cockroach


prothoracic
(T1)
mesothoracic
(T2)
metathoracic
(T3)
Thoracal-Coxal
Joint
Coxa
Trochanteral-
Femoral Joint
Femoral-
Tibial Joint
Femur
Coxal-
Trochanteral
Joint
Trochanter
Tibia
Tibia-Tarsal
Joint
Tarsi

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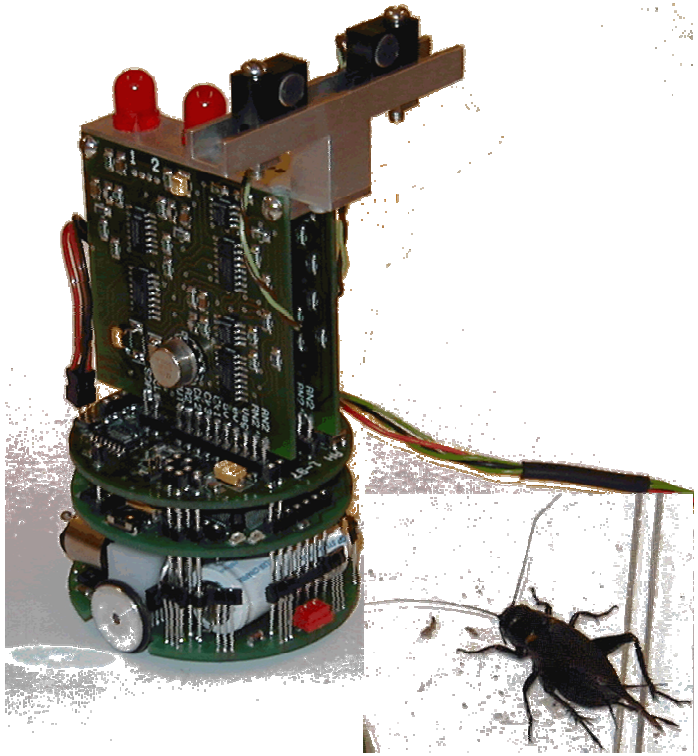
Khepera robot for cricket model, Cog humanoid robot

Khepera robot



Cog is a humanoid stimulus-response robot designed to learn from its environment, the way a child does.