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Brain-Based Control System for Animal-Like Companion Robots

An Analysis

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Technical Aspects of Multimodal Systems

07. January 2019



Outline

1. An Introduction to Companion Robots
2. The Miro Robot
3. Brain-Based Control System
 - Internal States
 - Social Patterns Generator
 - Spatial Behavior
4. Discussion
5. Conclusion



What are they?

Who are they for?

Some fields of applicability...

- ▶ Socialization
- ▶ Health Monitoring
- ▶ Rehabilitation
- ▶ Therapy
- ▶ Education
- ▶ Entertainment



Fig. 1: "Max" Robot [3]

Animal-Assisted Activities

Advantages

- ▶ Calming effect
- ▶ Reduces depression
- ▶ Triggers communication

Disadvantages

- ▶ Effort
- ▶ Diseases
- ▶ Risk of aggressive behavior



Fig. 2: "Paro" by PARO Robots



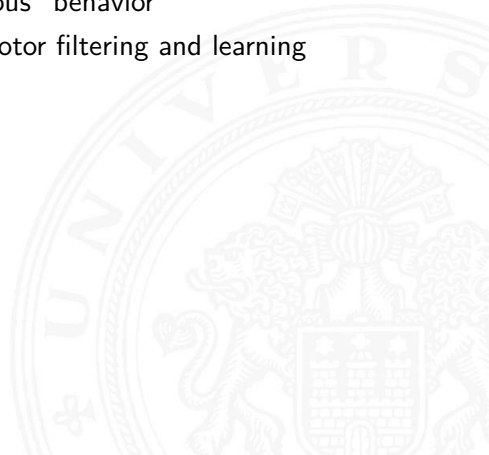
Fig. 3: "Miro" by Consequential Robotics

Video



Brain structures

- ▶ Spinal cord - Reflexes and hardware abstraction
- ▶ Brainstem - Simple, "instinctual" behavior
- ▶ Forebrain - Complex, "conscious" behavior
- ▶ *Cerebellum - Sensory and motor filtering and learning



Characteristics

- ▶ Four processing levels, three on-board
- ▶ Fast and simple / slow and sophisticated
- ▶ Accessibility is higher at the top of the processing stack
- ▶ Disassociation

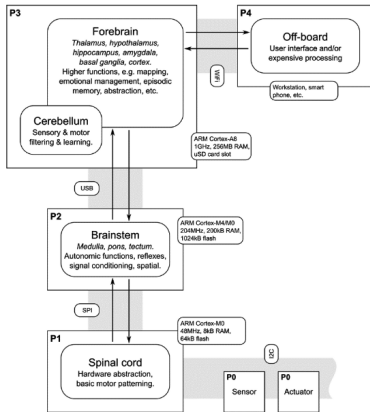


Fig. 3: Processing Stack

Spinal Cord

- ▶ Signal clean-up
- ▶ Cliff reflex
- ▶ Freeze reflex

Brainstem

- ▶ Management of Internal State (Affect)
- ▶ Social Pattern Generation
- ▶ Spatial Behavior
- ▶ Additional Functions

Forebrain

- ▶ Programmable





Affect

The circumplex model of affect

Valence/Arousal

Stimuli: touch, sounds, light levels and time of day

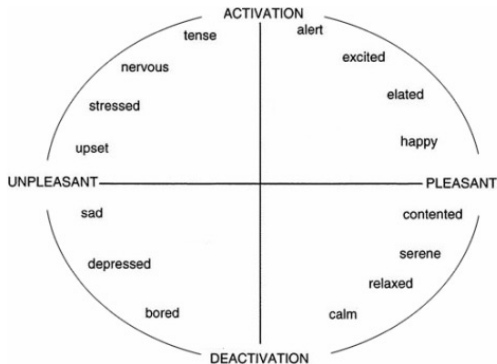


Fig. 4: Circumplex model of affect [6]

Social Pattern Generator (SPG)

Levels of valence and arousal will have an impact on...

- ▶ Voice
- ▶ Speed of motion
- ▶ Color of led lights
- ▶ Movements of tail, ears, eyelids, and neck

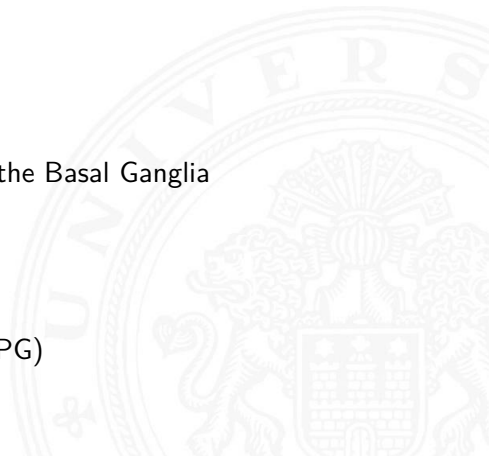


Fig. 5: Miro expressing its internal state through posture [1]



Step-by-step

1. Topographic salience map: movement and sound + intensity
2. Hard-coded filters
3. Behavior plan
 - ▶ Orient
 - ▶ Avert
 - ▶ Approach
 - ▶ Flee
4. Plan selection with model of the Basal Ganglia
 - ▶ Clean selection
 - ▶ Partial selection
 - ▶ Distorted selection
 - ▶ No selection
5. Motor pattern generation (MPG)





Other Function

- ▶ Sleep dynamics
- ▶ Estimation of self-configuration
- ▶ Gating of refferent noise



Control Architecture

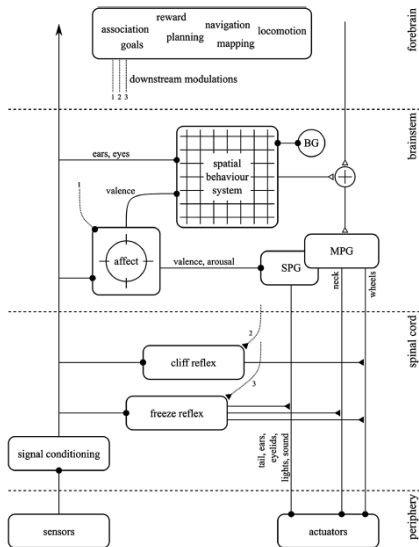
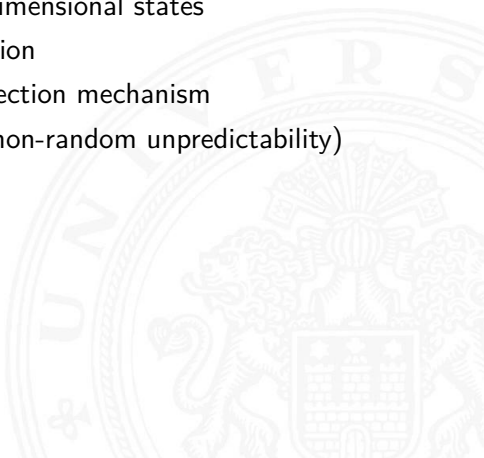


Fig. 6: Control Architecture of the Miro



Improvements compared to state of the art in animal-like companion robots Paro and AIBO:

- ▶ Biomimetic division of responsibilities
- ▶ Two-dimensional versus one-dimensional states
- ▶ Possibly-hierarchical organization
- ▶ Basal ganglia as an action selection mechanism
- ▶ Conflicting behavioral plans (non-random unpredictability)



Advantages and Disadvantages

Advantages	Disadvantages
Biomimetic	Complex
Life-like	Unpredictable
Modular	Unclear States
Fast Reflexes	Slow Decisions
Scalable	

Table 1: Advantages and Disadvantages of the Brain-Based Control System

Trade-off between biomimicry and simplicity
Benefits have not been proven



Suitable for...

- ▶ Specific kinds of therapy and rehabilitation
- ▶ Health/emergency monitoring
- ▶ Education and Entertainment
- ▶ Studying the brain

Not ideal for...

- ▶ Task-driven robots
- ▶ Any goal that can be performed with a simpler architecture





It introduces interesting biology-inspired mechanisms

It's a powerful research tool

A complex solution fit for complex problems

However...

Benefits so far are largely theoretical





The End

Any questions?



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