Modeling artificial metabolism and motivational autonomy in humanoid robots

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Supervised by
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Feel and Want node

- Affective modulation of embodied higher-level cognition (ESR8)
  - Metabolic regulation integrated in high level decision making mechanism
- Emergence of affective ‘representation’ and predictive capabilities (ESR7)
The nested levels of emotions
(Damasio, 2004)
Energy autonomous robots

Solar powered Mars rover

SOLO-TREC robot powered by ocean’s thermal energy
Ecobot (Bristol Robotics Laboratory)
The architecture (Lowe, R. et. al., 2010)

- The E-GasNet
  - GasNet - interfaces body (metabolic values) with sensori-motor control
  - Essential variable monitoring
- Artificial Metabolism
  - Microbial fuel cell – energy producing from two resources
- Grounded high level cognitive process
  - Active vision
- Evolutionary Algorithms
Energy autonomous wheeled robot
Motivation for a new body

- Insight to developmental psychology
  - Humanoid robot has closer structure to the human body thus could be a better model

- Industrial applications
  - *Legged moves better in non-smooth terrains*
  - *Robust to disturbances*
  - *More autonomous*
  - *Service robots*
What should be changed?

- Energy cost / movement
- Locomotion pattern
- Gaze around
- Field of view / active vision
- Reaching / Grasping the resource
- Evolutionary algorithm
Move towards resources

- Left right Motor E-Gas NET nodes ↔ motors
- Different walking patterns - develop energy efficient learning
- E-Gas net node ↔ each joint
- E-Gas net node ↔ parameters to a CPG
- How to do the mapping?

Diagram:
- Left motor speed ↔ Turn left
- Right motor speed ↔ Walk forward
- Turn right
Develop energy efficient motion pattern (Kimura et. al., 2005)

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of trials</th>
<th>Dimensionless cycle duration</th>
<th>Dimensionless stride length</th>
<th>Dimensionless speed</th>
<th>Stance phase duration in In (%)</th>
<th>Braking duration in In (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1-year-0-month</td>
<td>104</td>
<td>4.413**, 1.162</td>
<td>1.171**, 0.365</td>
<td>0.2489**, 0.1190</td>
<td>4.259**, 0.100 (91)</td>
<td>3.679**, 0.310</td>
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<tr>
<td>1-year-3-month</td>
<td>133</td>
<td>3.920**, 0.931+++</td>
<td>1.388**, 0.345+++</td>
<td>0.3744**, 0.1276+++</td>
<td>4.235**, 0.083+ (122)</td>
<td>3.713**, 0.209</td>
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<td>1-year-6-month</td>
<td>163</td>
<td>3.563, 0.765+++</td>
<td>1.425**, 0.301+++</td>
<td>0.4243**, 0.1416++</td>
<td>4.212**, 0.081+++ (156)</td>
<td>3.813**, 0.221+++</td>
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<td>1-year-9-month</td>
<td>65</td>
<td>3.918**, 0.934++</td>
<td>1.460**, 0.228+++</td>
<td>0.3987**, 0.1280+++</td>
<td>4.237**, 0.078 (63)</td>
<td>3.856**, 0.218++</td>
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<td>2-year-0-month</td>
<td>43</td>
<td>3.578, 0.880+++</td>
<td>1.463**, 0.226+++</td>
<td>0.4362*, 0.1351++</td>
<td>4.215**, 0.084+ (42)</td>
<td>3.819**, 0.287+</td>
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<tr>
<td>3 years</td>
<td>33</td>
<td>4.351**, 0.743 (30)</td>
<td>1.496**, 0.278+++ (30)</td>
<td>0.3624**, 0.1101++</td>
<td>4.237**, 0.058 (31)</td>
<td>3.906, 0.189+</td>
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<tr>
<td>Adults 1</td>
<td>27</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Adults 2</td>
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<td>3.471, 0.244+++</td>
<td>1.643, 0.171+++</td>
<td>0.4767, 0.0691+++</td>
<td>4.163, 0.025+++</td>
<td>3.926, 0.072+++</td>
</tr>
</tbody>
</table>

- Algorithm used to assess human energy efficiency over a number of different dimensions
- Compare architecture performance to humans data
Reaching / Grasping the resource

- Solve the grasping problem → action primitive
- Self-maintaining a quantity of sufficient energy to finish the movement (grasping, consuming)
  - Learning how much energy is needed for behavior
- Action selection – chose appropriate action with the current amount of energy
Study the difference

- Compare performance
  - Number of generations to achieve fitness
  - Type of controller evolved
  - Times to reach to resources, patterns of behavior

- Parameters to modify
  - Field of vision
  - Energy constraints
  - Crawling vs walking
Implementation

controller
Java

Body / env.
Webots

Motion sequences
- Step forward/ backward
- Side step
- Turn 40deg, 60deg
More generic architecture

controller
Java

mediator
Python or C++

tcp/ip socket

NaoQi

modules
Motion Videoinput

Real Nao

Sim. Nao
Portability to another robots - iCub

controller
Java

mediator
Python or C++

YARP

Real BOT

Sim. BOT

tcp/ip socket
Summary

- State of the art
  - affective cognitive architectures and
  - autonomous agents
- Play with the robots
  - NAO, epuck, iCub
- Modify / reimplement
  - Architecture for artificial metabolism and motivational autonomy
Future work

- More robots
  - Icub, Asimo, Anybot
- Learning abilities
- More complex environment
  - Dynamic resources
  - Obstacles
  - Different objects
- Climb up the tree
  - More complex emotions
References:

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Thanks for the attention!