

Integrating Cognition, Emotion and Autonomy

Tom Ziemke

School of Humanities & Informatics
University of Skövde, Sweden

tom.ziemke@his.se

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Mind vs. Life

- *"That mind requires life is often stated, and even more commonly assumed."*

(Margaret Boden's plenary abstract)

- Is it really?
- AISB 2005 machine consciousness symposium vote: only 3 out of about 30 participants thought that cognition/consciousness requires life/autopoiesis

Embodiment?

- Different notions of embodiment emphasize:
 - Interaction (agent-environment)
 - Structural coupling (agent-environment)
 - Adaptation (to an ecological niche)
 - Physicality
 - Morphology
 - Complex interplay of morphology, neural processes and environment
 - Grounding of cognition/representation in sensorimotor processes (e.g. simulation theories)
 - Facilitation of social interaction
 - Autopoietic organization of living organisms

Embodiment à la Murray

- "a spatially localised body using a sensory apparatus fastened to that body"
- "shared viewpoint, from which they can be indexically directed to the world"
- parallel-to-serial transition "perhaps the essence of consciousness, of what it means to be a singular, unified subject"
- Is that it?

Organismic Embodiment?

- examples:
 - Maturana & Varela's (1980) work on autopoiesis and the biology of cognition
 - von Uexküll's (1928) theoretical biology
 - Damasio's (1994, 1999) theory of emotion and consciousness
 - Barandiaran & Moreno's (in press) notion of emotional embodiment

Why organisms?

- Philosophy: see M. Boden's plenary talk
- Science:
 - All interesting cognitive systems we know of are organisms; it's those we want to understand
- Engineering:
 - Living organisms have a range of highly useful capacities (self-maintenance, self-repair, etc.)
 - Robots with energy autonomy, etc.
 - Autonomic computing systems
- Historical:
 - Dennett (1978) - "*Why not a whole iguana?*"
 - Brooks (1989a) - "to build *complete creatures* rather than isolated cognitive simulators"

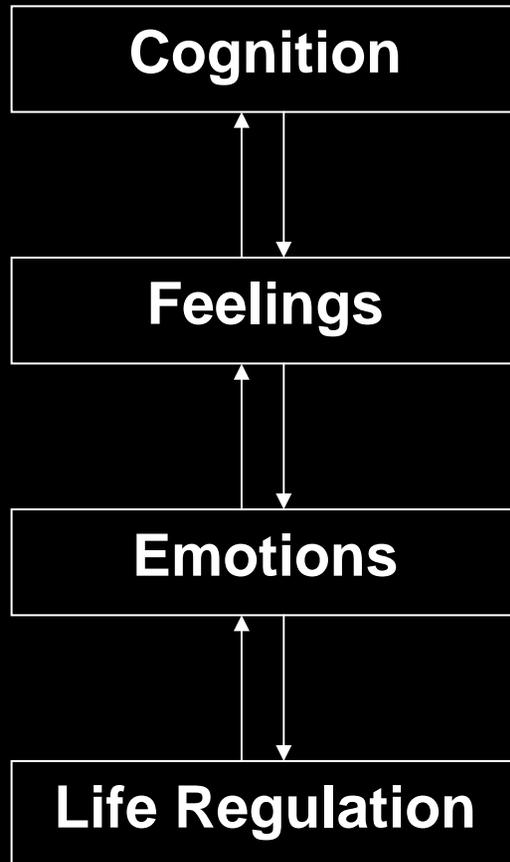
Internal Robotics (Parisi, 2004)

- ... behaviour is the result of the interactions of an organism's nervous system with both the external environment and the internal environment, i.e. with what lies within the organism's body.
- While robotics has concentrated so far on the first type of interactions (*external robotics*), to more adequately understand the behaviour of organisms we also need to reproduce in robots the inside of the body of organisms and to study the interactions of the robot's control system with what is inside the body (*internal robotics*). (p. 325)

Barandiaran & Moreno (in press)

- sensory-motor nervous system (SMNS) vs. nervous system of the interior (INS) (cf. Edelman, 1989)
 - INS: neuroendocrine system, autonomic nervous system, limbic system, etc.
- emotion ~ complex interplay between INS and SMNS (e.g. Damasio, 1994; Lewis, 2005)
- emotional embodiment:
 - the modulatory capacity of emotional dynamics is recruited to adaptively modify the SMNS

Levels of Regulation (Damasio, 1999)



complex, flexible, and customized plans of response are formulated in images and may be executed as behavior

images (representations) of sensory patterns signaling pain, pleasure, and emotions

complex, stereotyped patterns of response, which include primary, secondary and background emotions

relatively simple, stereotyped patterns of response, incl. metabolic regulation, reflexes, the mechanisms behind pain and pleasure, drives and motivations

ICEA project - motivation

- Jan 2006 – Dec 2009, 100+ person-years, 8 million euros
- “the emotional and bioregulatory mechanisms that come with the organismic embodiment of living cognitive systems also play a crucial role in the constitution of their high-level cognitive processes, and
- models of these mechanisms can be usefully integrated in artificial cognitive systems architectures, which will constitute a significant step towards truly autonomous cognitive systems that reason and behave, externally and internally, in accordance with energy and other self-preservation requirements, and thus sustain themselves over extended periods of time.”

Consortium

- Skövde Cognition & AI Lab – Tom Ziemke (coordinator)
- Animat Lab, Paris – Jean-Arcady Meyer
- College de France – Sidney Wiener
- CNR, Rome – Baldassarre, Parisi, Nolfi
- Sheffield - Tony Prescott, Peter Redgrave
- Bristol Robotics Lab – Chris Melhuish
- BAE Systems, Bristol – Hector Figuereido
- Cyberbotics – Olivier Michel
- Hungarian Academy of Sciences – Peter Erdi
- Autonomous Systems Lab, Madrid – Ricardo Sanz

Emotions (Damasio, 2004)

- ... emotions are bioregulatory reactions that aim at promoting, directly or indirectly, the sort of physiological states that secure not just survival, but ... [also] well-being. (p.50)
- ... emotional responses target both the body and other regions of the brain ... The responses alter the state of the internal milieu (using, for example, hormonal messages disseminated in the bloodstream); the state of the viscera; the state of the musculoskeletal system, and they lead a body now prepared by all these functional changes into varied actions or complex behaviours. (p. 51)

Emotion (Petta, 2003)

- Emotion can be viewed as a flexible adaptation mechanism that has evolved from more rigid adaptational systems, such as reflexes and physiological drives ...
- The flexibility of emotion is obtained by decoupling the behavioral reaction from the stimulus event. The heart of the emotion process thus is not a reflexlike stimulus-response pattern, but rather the appraisal of an event with respect to its adaptational significance for the individual, followed by the generation of an action tendency aimed at changing the *relationship* between the individual and the environment. (p. 257)

Feeling (Damasio, 1999)

- feeling = “the mental representation of the physiologic changes that occur during an emotion”
- while emotions involve bodily reactions, feelings (mental images of those reactions) allow the cognizer to temporarily decouple its cognitive processes from its immediate bodily reactions
 - e.g. anticipation of bodily reactions in the planning of behavior
 - “as if body loop” (Damasio)
 - a neural “internal simulation” (cf. Murray’s and Owen’s talks) that uses the brain’s body maps, but bypasses the actual body

Feelings of emotion (Damasio, 2004)

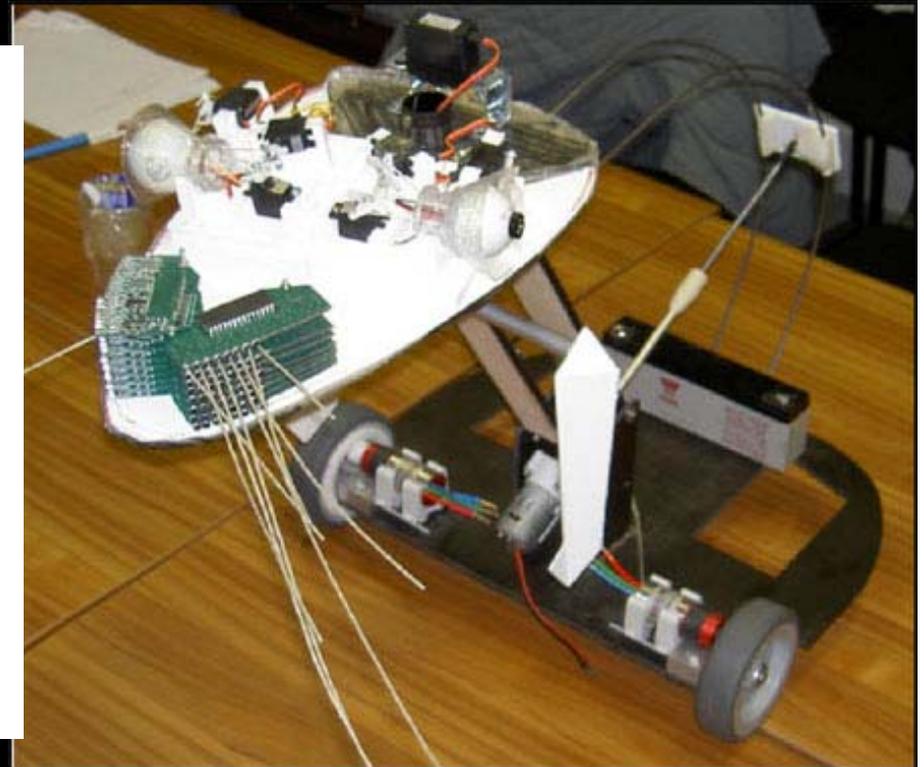
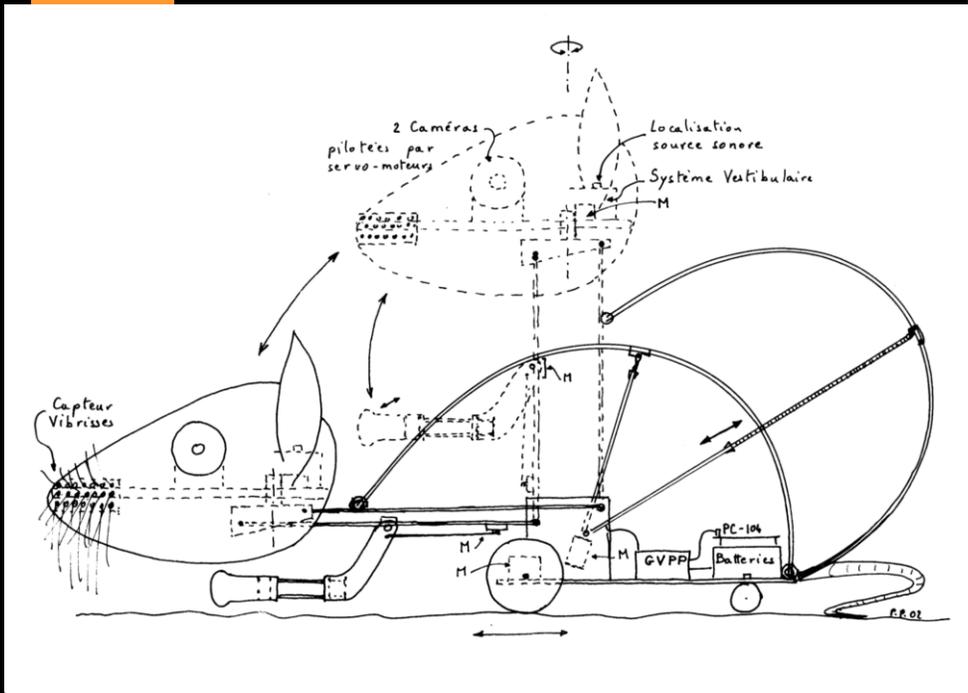
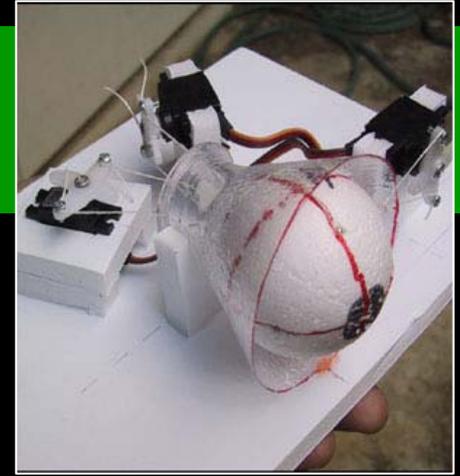
- The essence of feelings of emotion is the mapping of the emotional state in the appropriate body-sensing regions of the brain. (p. 52)
- Whereas emotions provide an immediate reaction to certain challenges and opportunities ... [t]he adaptive value of feelings comes from amplifying the mental impact of a given situation and increasing the probabilities that comparable situations can be anticipated and planned for in the future so as to avert risks and take advantage of opportunities. (pp. 56-57)

ICEA - The rat as a starting point

- Massive literature on behavior & neurobiology
- Rather homologous to man
- Clever, intelligent, adaptive, compact
 - a model that works
- Realizable target for a four-year project
 - compared to human
- Complements existing EC-funded Cognitive Systems projects
- But: will surpass (selected) rat cognitive capacities

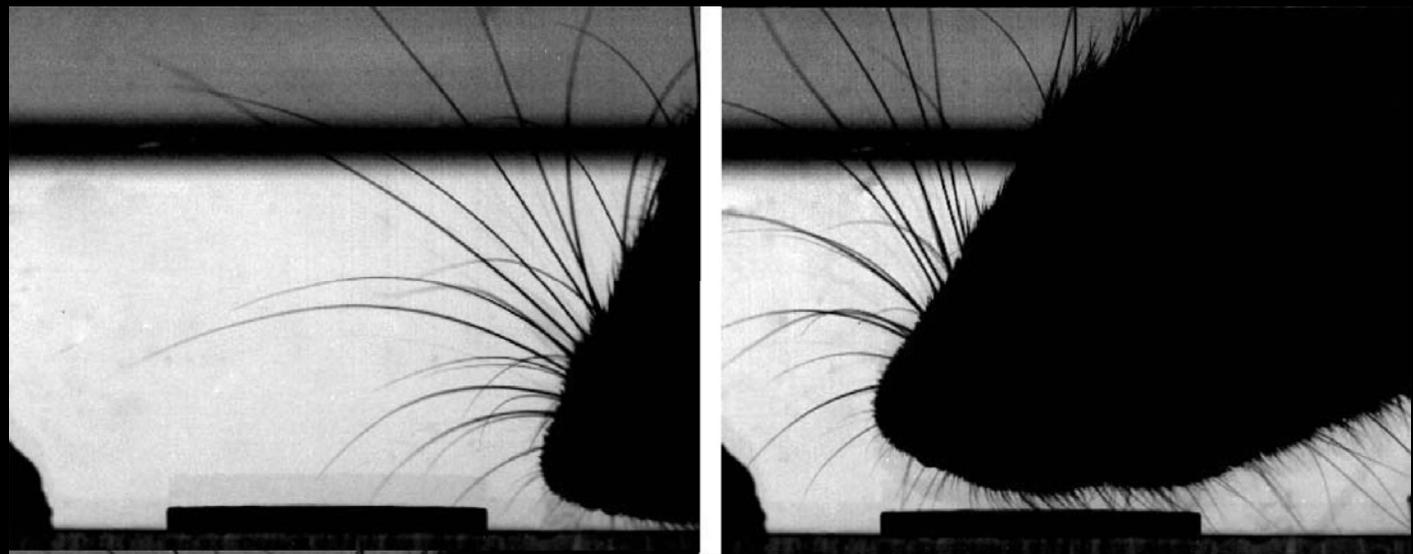
ICEAbot

- Rat-like physical robot platform
- Builds on the Animat Lab's previous *Psikharpax* project



Active whisking

- active touch for perception and spatial cognition
 - a neck with 3-DOF two arrays of macro-vibrissae, and
 - an array of smaller micro-vibrissae that provide a form of tactile ‘fovea’ for close-up examination of surfaces
 - based on high-speed digital videography of real rats (cf. Sheffield’s posters & demo)



ICEAsim

- Rat-like simulation platform
 - based on Cyberbotics' Webots toolkit
 - used by all modelers in the consortium
 - Integration of models
 - based on ICEAbot
 - but with additional features: active whiskers, metabolism, etc.
- Will be made available for free to other researchers

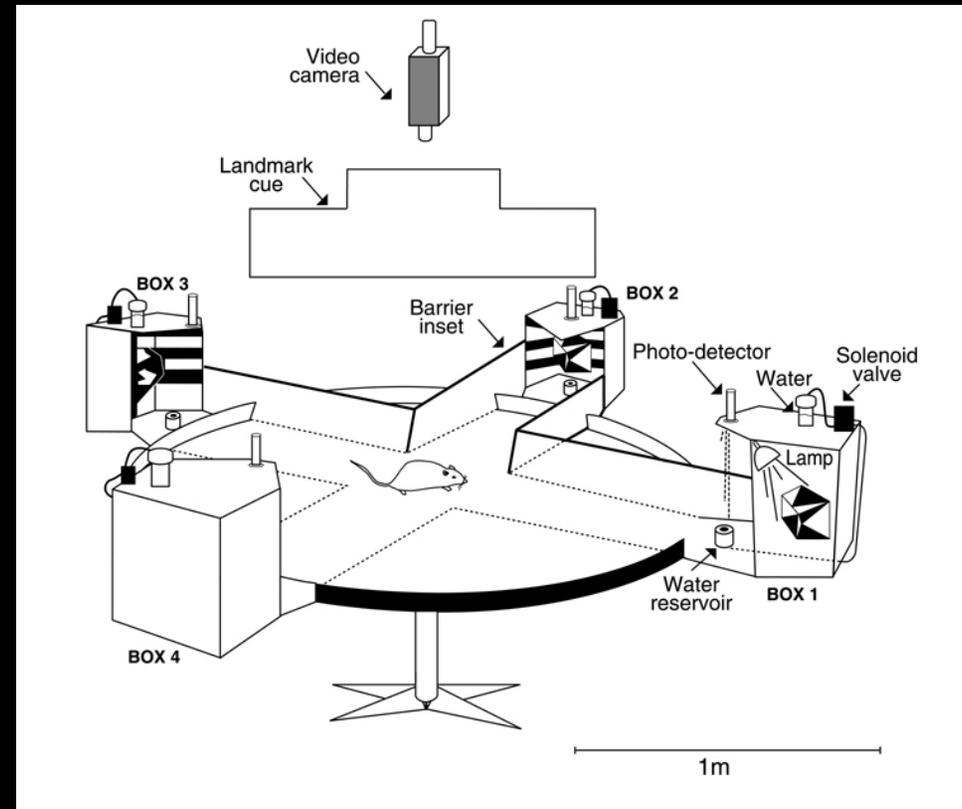
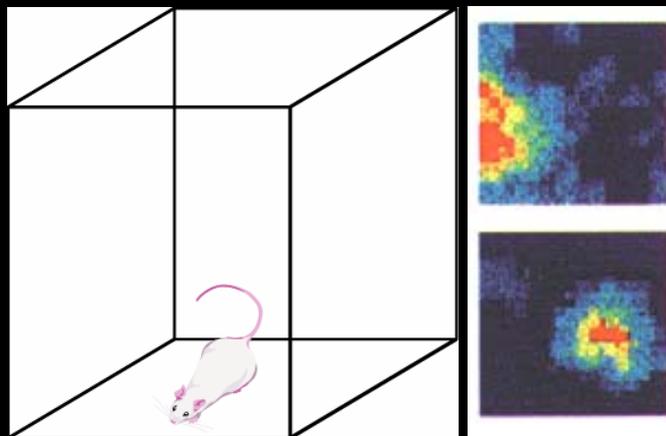


Project elements

- overall volume: 100+ person-years of funded research
 - about 10% neurophysiology, rat experiments
 - about 80% comp. modelling, robotics, systems integration
 - about 10% theoretical integration
- alternative breakdown:
 - three main ‘chunks’, 25% each
 - central ICEA integrated robot and simulation platforms
 - motivated spatial cognition/behaviour
 - emotion-based representation/cognition
 - smaller ‘chunks’
 - layered self-defense architecture
 - energy autonomy

Spatial behavior & cognition

- rat neurophysiology
- computational neuroscience models at different levels of abstraction

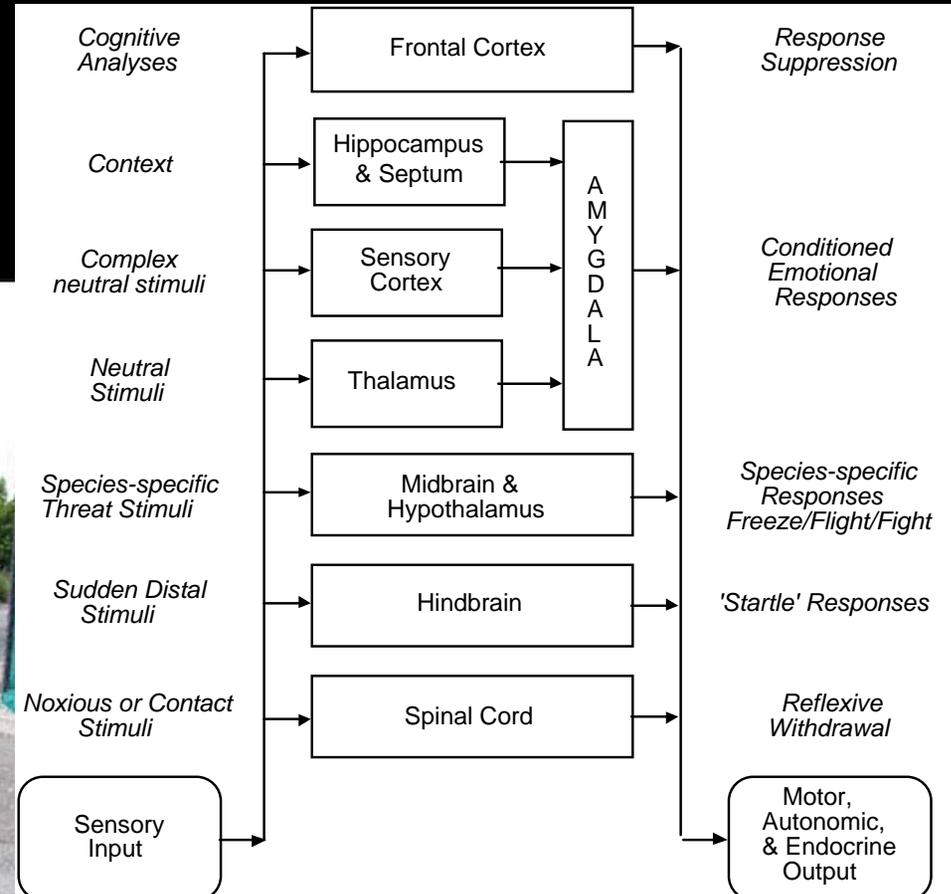


Mammalian brain structures modeled

- *cortex* - planning, motivation, working memory, and analysis of sensory data
- *cerebellum* - anticipation, prediction
- *amygdala* - emotion and classical conditioning
- *basal ganglia* (incl. nucleus accumbens) - action selection sequencing, and reinforcement learning (operant conditioning)
- *hippocampus* - spatial and contextual memory
- *superior colliculus* - orienting
- *hypothalamus* - drives
- *brain-stem* - bio-regulation and pattern generation

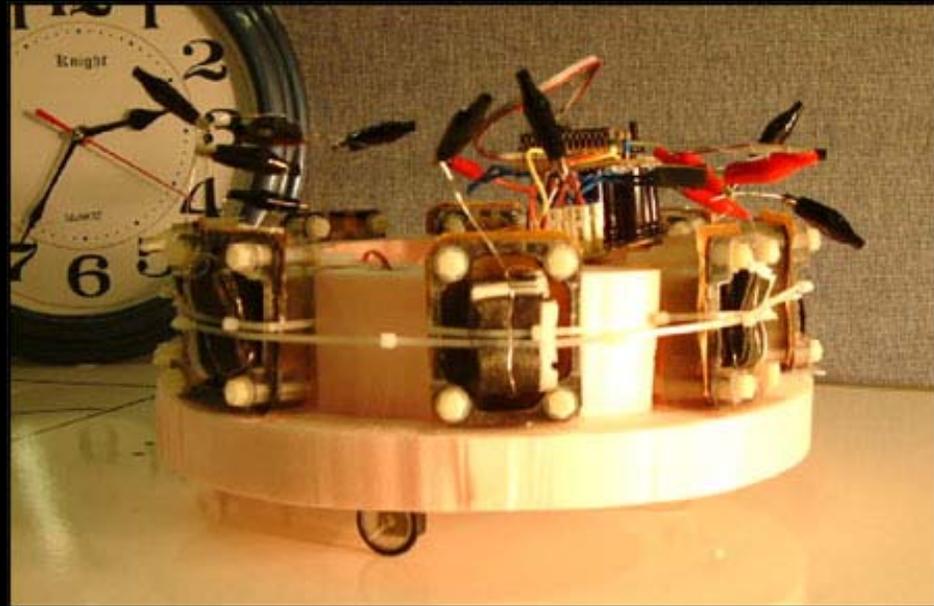
BAEbot

- Layered defence architecture (cf. Peter Redgrave's talk) on an all-terrain vehicle



BREADbot

- "Bio-regulation and energy autonomy with digestion"
- Based on the BRL's current work on energy autonomy using microbial fuel cells
- Coordination of internal homeostasis and effective foraging behavior



Anticipation, imagination, planning

- starting point: simulation/emulation theories of cognition/representation as based on simulated agent-environment interaction
 - e.g. Hesslow, Grush, Barsalou
 - Thought ~ simulated sensorimotor interaction
 - Damasio's "as-if body loop"
 - e.g. anticipation of bodily/emotional reactions in the planning of behavior
 - What's the right level of abstraction?
- beyond the real rat's cognitive capacities (?)

Integrating everything ...



Lines : 256
Quads : 554
Triangles : 78

... to be continued

ICEA Summary

(in terms of Jeff's BBD principles)

- *"Incorporate a simulated brain ..."*
 - ICEA: integration of partial models of mammalian brain
- *"Active sensing and ... movement in the environment"*
 - ICEA: rat-like robots doing rat-like tasks
- *"Engage in a behavioral task"*
 - ICEA: rat-like tasks in rat-like environments
- *Categorization without a priori knowledge/instruction*
 - ICEA: in particular for abstraction/representation
- *"Adapt behavior when an important ... event occurs"*
 - ICEA: emotional appraisal, value systems, etc.
- *"Comparisons with experimental data acquired from animals ..."*
 - ICEA: based on and compared to rats