bio-robotics, neuro-engineering: why?

the dream of robotics: stupid & dangerous work should be done by robust, intelligent and reliable machines, not by unreliable people

neuroscience at the cutting edge of engineering: 'biomimetics', 'neuromorphics'

<< principles of biological information processing are very successful

• fast: digital-number crunching vs. analogue deployment of quick'n'dirty strategies
• robust: resistant against perturbations (self-stabilising)
events (redundant) injury (healing, self-organising)
• versatile: operates in many environments, flexible
response to changes, intelligent
• cheap: minimise size (maximise payload),
omeune functionalty (revolution: artificial life),
maximise output of mass production

robots celebrity Rodney Brooks: the marriage of kids' dreams and philosophers' nightmares?

insect orientation and navigation

robots can be treated as models to describe behaviour
(cf. Braithsburg's 'vehicles' 'synthetic psychology') (cf. Webb 2002)

• phonotaxis in crickets (Barbara Webb): female crickets
are attracted by specific songs of male crickets, find the
cluster by tracking the sound source

navigation & orientation of ants (Cataglyphis) in
Sahara: integration of optic flow, sun & polarisation
compass, path integration (dead reckoning),
landmarks > Sahabot 2 (Lambrinos, Weber et al.)
panoramic vision

can be exploited by using panoramic cameras modelled after insect visual systems: lens & parabolic mirror (Chahl & Srinivasan 1997)

used in flying robot (blimp): gondola Melissa (AILab Zürich) is a test 'platform' to study the integration of motion information (flow fields) for estimating flight speed and travelling distance (no proprioceptive information)

panoramic vision cont.

used as instrument to study visual ecology (Zeil & Zanker)
- camera mounted on gantry
- controlled by microprocessor
- travelling on defined paths
>> analyse motion flow fields in natural environments

autonomous vehicles: flies >> helicopters

the ultimate goal is to build fast flying, autonomously stabilising and navigating robots: UAV (unpiloted airborne vehicles)
- autonomous helicopter (no pilot, no remote control), first results: visually mediated hovering, terrain following autopilot (Biorobotic Vision Laboratory, Canberra)
- AVATAR (Autonomous Vehicle Aerial Tracking And Reconnaissance), formation flying through the coordination of many autonomous flying robots (Robotics Research Lab, USC)
robofly: aerodynamic problems

surprising complications: unexpected issues arising from specifications of motor system - insect aerodynamics is merely understood, requires complicated aerodynamics

some science fiction: fly-sized autonomous robots (Berkeley Robotics Laboratory)

autonomous airborne vehicles: political issues

the real goal behind many of these efforts: robotic bombers, etc.
- strategic advantages over cruise missiles
  - minimise loss of expensive guidance equipment
  - potential to 'hunt down' mobile, re-locatable targets
  (what kind of ‘progress’ between first and second Iraq war?)

  * unmanned combat air vehicles (UCAV) will keep humans in control but out of danger
  (this view depends on which side you are)

most funds for this research originate from US Air Force, DARPA, NASA, Office of Naval Research

perhaps more comfortable: the soft grip

surgical robots (offer high precision and potential to minimise damage) require advanced mechanical control (for instance, to handle compliant tissues) of tools - what has biomimetics to offer?

robots mimicking cockroaches ('bugbots'); originally designed to walk in unstructured environments with little sensory feedback by robust design of locomotion system

> passive rubber spring, like springy resilin-lined arthropod joints, for passive stabilisation

same design principle extended to the gripper (attached to front limbs):
> can be adjusted in stiffness for fine deployment of grip force

( Harvard Biosrobotics Laboratory)
**tele-manipulation**

remotely controlled hand-like actuators: an emerging field of technology

in search of ‘natural grasp’:
artificial hand built uniquely to test the force feedback glove (Laboratoire de Robotique de Paris) >> copy mechanical structure of hand:
4 + 1 fingers, pivot articulation, feedback control angle & force

latest collaborative efforts (NASA Jet Propulsion Laboratory (NDEAA), CalTech, Sheffield University, University of Pisa):
advanced robotic arm-hand system

[Image 183x619 to 278x690]

**artificial limbs**

conventional prosthesis design: 1849 patented by F. Palmer, earlier models improved (increased mobility) to supply 30,000 veterans from the Civil War (… technology for yet more victims of wars, post–Iraq II)

obvious demand for biologically inspired and intelligent engineering in prosthesis

anthroform arm project:
attempt to copy functional anatomy of arm as close as possible
- fiberglass bones
- pneumatic actuators (muscles)
- surgical replacement joints
- simulated neural control circuits (Univ. Washington Biorob. Lab.)

[Image 77x570 to 158x631]

**smart artificial limbs!**

attachment to patient? mechanics & control! >> ‘neuro-prosthesis’ is the next step:
chronic electrode implants to connect artificial limb to nervous system

W. Craelius, Rutgers: ‘Dextra’
artificial hand tapping into the residual sensorimotor system to activate replacement body parts:
- pick up electric signals from more proximal muscles/tendons
- learn to control ‘phantom’ fingers
- independent control of 5 fingers

connecting artificial limb to nervous system!!
here peripheral nerve/muscle: what about the CNS?

[Image 80x168 to 118x223]
the final goal: brain-machine interaction

the key animal experiment: remote control brain >> robot arm

- chronic implantation of large electrode array (96)
- long-term recordings
- correlation analysis with arm movements
- transfer data through web to robotics experts
- drive robot arm with transmitted signals

- the neuro-scientist (M. Nicolelis) : Weisberg et al. 2002
- the owl monkey
- the robot arm

human brain-machine interaction?
from science to science fiction

Department of Cybernetics at the University of Reading: Kevin Warwick

- Project Cyborg 1.0
- Project Cyborg 2.0

- A sophisticated new microelectronic implant has been developed that allows two-way connection to the nervous system. In one direction, the natural activity of nerves are detected and in the other, nerves can be activated by applied electrical pulses. It is envisaged that such neural connections may, in the future, help people with spinal cord injury or limb amputation.

food for thought: merging mind & machine

- speed of technological development (Moore's law)
- increasing relevance of IT-based technologies
- compare to speed of evolution...

- growth rates of WWW
- acceleration of computing speed, software efficiency (neural nets, genetic algorithms)
- novel interfaces between nervous system and electronic devices

when will the engine of evolution generate secondary intelligence that will exceed the intelligence of its creators? (Kurzweil 1999)

- enthusiastic popular reception of defining technology of 21st century: "Robo sapiens" predicts the fusion, or at least close coexistence, of man and intelligent machine
- "apocalyptic optimism"
other highlights of biorobotics
- electrosensory submarines: electric fish
- walking in legged robots: insects
- neural networks: software for pattern generation, adaptive systems, learning

and even more highlights
- division of labour in insect societies: groups of collaborating robots
- chip design from principles of cortical architecture, neuroinformatics (flowfield processor)
- growing and learning biological systems: self-assembling structure & behaviour; e.g. HYDRA

the most popular toys...
- Khepera Robot Mini Platform
- Lego Lab University of Aarhus: Jungle Cube
- Lego mindstorms: vehicles for kids
summary:
(wo)man’s intelligent creatures

• basic concepts, variety of methods & applications of bio robotics & neuroengineering
• copying from nature, extending biological systems
• speculating about the future relation between man and machine

specific reading

• Brooks, R 2000 “From robot dreams to reality” Nature 406, 945-946
• Crusius, W 2002 “The Bionic Man: Restoring Mobility” Science 295; 1018-1021
• Kurzweil, R 1999 “The coming merging of mind and machine” Sci Am. Special Issue 1999
• Weh, R 2002 “Can robots make good models of biological behaviour?” Behavioral and Brain Sciences 24, 1833-1858

complete reference list at:
http://www.pc.rhul.ac.uk/zanker/teach/Ps3060/L5/Ps3060_5.htm

… it’s fun time …

(posters ??)
see http://www.pc.rhul.ac.uk/zanker/teach/Ps3060/Ps3060_poster.htm )