Biologically-Inspired Robot for Space Operations

Ron Jacobs, Ph.D.

A NIAC Supported Research Project
Artwork by Ginny Clark
Biologically-Inspired Approach

- Provides for flexible and versatile systems
  - Subtle and huge forces dependent on task requirements
  - Multiple yet stable joints due to intrinsic mechanical features
  - High functionality of limbs with low mass and inertia

- Employs intelligent behavior
  - Use of *if-then* rules in control and decision making
  - Able to reason and interact
  - Adapts to changes in task demands and environment
Leonardo da Vinci
Integration of Biology and Physical Science

Johannes Borelli
Integration of Biology and Physical Science

From: De Motu Animalium, F Mosca, Napels 1734
Implementation of Biologically-Inspired Approach

- Employs anatomical and physiological constraints
  - Force-length and force-velocity characteristics of muscles
  - Self-limiting joints
- Takes advantage of control features that enhance performance of biological systems
  - Focuses on if-then rules for intelligent control and behavior
  - Utilizes functional muscle groupings for required force and position control
- Requires a relatively small computational load
Analysis and Simulation of Biological Movements and Control

Courtesy of Musculographics Inc. and Dr. Rick Neptune, VA Hospital Palo Alto, CA
Hardware implementation
First prototype of legged robot
Conventional Robotic Design
Heavily Dependent on Control
Biologically-Inspired Design
Intrinsic Mechanical Feedback Control
Dr. Ron Jacobs

Technical Feasibility - Video

First prototype

- Legged robot with 18 artificial muscles

NIAC Phase I

- Project started in November 1998

Abilities to date (after four months)

- Standing (open loop)
- Disturbance rejection while standing (open loop)
- Walking movements (open loop)
Benefits of Biologically-Inspired Approach

- Allows for intelligent control in a flexible yet stable system
- Facilitates travel and operation in rough terrains and difficult conditions
- Facilitates high functionality and versatility in a low mass system
First prototype demonstrates the power of the biologically-inspired approach

- Implementation of artificial muscles
- Utilization of intrinsic mechanical properties for local stability
- Implementation of relatively simple control rules
- Control of flexible multi-joint system
- Implementation of if-then rules for functional muscle groupings
- Provision of required force and position control
Design and Development Issues
The Next 10 years

- **Technical issues**
  - Artificial muscles
  - Sensors
  - Self-contained power
  - Intelligent control

- **Mobility and operation issues**
  - Travel on even terrains
  - Travel on rough terrains and difficult conditions
  - Transformation and versatility
  - Maneuverability
  - Object manipulation
Design and Development Issues
The Next 10 years

- Intelligent agent issues
  - Autonomous nature
  - Problem solving and reasoning - especially in novel situations
  - Specialization of agent’s performance

- Community of intelligent agent issues
  - Communication and reasoning among agents
  - Interaction and reasoning with remote scientist - *human extension*
  - Cooperation and problem solving
NASA Benefits of Biologically-Inspired Approach

- Provides community of intelligent agents
  - Travel and operate in rough terrains and difficult conditions
  - Focus on intelligent control, interaction and cooperation
  - Ideal for exploration beyond the solar system
  - Ability to explore novel opportunities

- Provides flexible and versatile systems
  - High functionality in a relatively low mass system
  - Human-like features ideal for remote human interaction
Community of Agents

Art work by Ginny Clark
Futuristic Vision of Biologically-Inspired Approach
NIAC Supported Project Team

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