Biologically Inspired Trunk and Tentacle Robots

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Overview

• Tongue, trunk, tentacle robots – biologically inspired
• Snakes and hard backbones
• Continuum trunks and soft tentacles
• Summary
Conventional Robots

- Traditional robots “anthropomorphic”
- Based around long rigid link elements
- Good for precision tasks in well structured environments
- Severely limited in cluttered environments
- Poor for adaptation to “unstructured tasks”
Trunk and Tentacle Structures

- More maneuverable backbone
- Can “wind around” environment better
- Enter, operate in tight spaces
- Envelop, grasp irregularly shaped objects

War of the Worlds, Paramount, 2005
Robot Trunks and Tentacles: How?

- Numerous examples in nature
- Vertebrate and invertebrate structures
Biological Inspiration – Elephant

• Motivation for our initial efforts at Clemson
Example: Clemson Elephant Trunk (~2000)
Biological Inspiration - Snakes

- Howie Choset (CMU, talk earlier today)
- Rob Buckingham (OCR, talk later today)
Example: Clemson Elephant Trunk

Still rigid components
Soft “Continuum” Robotic Manipulators

- Inspiration from biology - soft, flexible, continuous appendages ("tongues, trunks, and tentacles")
- Compliant operation in unstructured/cluttered environments
- Rich history, back to 1960’s
Natural Continuum Structures

- Exploration, sensing, manipulation

Stability and balance

Fast, dynamic target acquisition
Biological Inspiration – Octopus

Remarkable diversity and complexity of movement in soft structure

- At any point on arm:
  - elongation, shortening, bending, torsion, variable stiffness
DARPA/DSO OCTOR Project (2003-07)

Univ. of North Carolina, Chapel Hill
Biomechanics, functional morphology of cephalopods

Marine Biological Lab, Woods Hole:
Cephalopod behavior

Weizmann Institute
Mathematical modeling, motion analysis of octopus

City Univ. of New York
Artificial suckers

Clemson University:
Electrical and computer engineering, psychology

Penn State Univ:
Mechanical engineering, materials science

Hebrew University:
Cephalopod neuromuscular control

DARPA BioDynotics Program

sOft robotiC manipulaTOR (OCTOR)
Example: DARPA Octarm (~2006)
Biological Inspiration: Plants

- In particular, vines
Example: NASA Tendril
Biological Inspiration - Squid
Example: Octarm

Grasping and manipulation

Prey capture
How are they Made?

• Fairly wide design space
  • backbone type (segmented, continuum)
  • actuation type (motors/tendons, artificial muscles)
  • compliance/rigidity
  • extension/bending (torsion)
  • operation/control strategy
Making Them Work is Not Easy!

- Many degrees of freedom to coordinate, sense
  - Passively/actively controlled
  - Non-intuitive movements for operators
- Model and non-model based operation
  - Kinematic models fairly well established
  - Dynamic models emerging
Summary

• New generation of robots corresponding to biological “tongues, trunks, and tentacles”
• Fairly wide design space
• Expanding corresponding body of theory
• Preferred design strongly a function of application
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