Towards an origami based compliant modular system for deep space exploration: the next generation of CubeSat

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Our concept: swarm of robotic CubeSat

Phase I: Folding/Unfolding
Phase II: Solar sailing
Phase III: mapping
Phase IV: active airbag/feather landing
Phase V: Exploitation

Central unit
Relay unit
Mapping unit
Robotic unit
Our concept: swarm of robotic CubeSat

- Versatile
- Upgradable
- Affordable
- Reusable

Phases:
- Phase I: Folding/Unfolding
- Phase II: Solar sailing
- Phase III: Mapping
- Phase IV: Active airbag/feather landing
- Phase V: Exploitation
Outline

1. Background
   • Modular robotics
   • Origami robotics
   • Bio-inspired approach

2. Hardware contribution
   • Compliant membrane
   • Artificial muscle actuation
   • Exoskeletons

3. Control
   • Cave exploration
   • Multi-robot coordination
   • Self-reconfiguration

4. Scenarios
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4. Scenarios
Background: modular robotics
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M-Blocks, MIT
SMORES-EP, UPenn
Superbot, USC

Roombots, EPFL
M-TRAN, AIST
Polybots, PARC
ATRON, USD

All images are the property of their respective authors.
Background: origami robotics
Versatility

Robustness

Roombots reconfiguration: from tripod to snake

http://biorob.epfl.ch/roombots
Biorobotics Laboratory, EPFL, Lausanne, Switzerland. November 2013.
Lower performance

Locomotion of a quadrupedal structure made of five Roombots modules

http://biorob.epfl.ch/roombots
Biorobotics Laboratory, EPFL, Lausanne, Switzerland. February 2014.
Bio-inspired approach
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Hardware contribution

Compliance | Soft actuation | Differentiation

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Hardware contribution

Compliance

Smart materials

Smart assembly

Soft actuation

Artificial muscles

Differentiation

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Hardware: robotic exoskeletons

Exoskeletons

- Rigid Core
- Soft envelope
- Artificial muscle

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Hardware contribution

Compliance

Soft actuation

Differentiation
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4. **Scenarios**
Control: from individual units to colony

Exploration

Coordination

Reconfiguration

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Control: from individual units to colony

Exploration: Caves exploration

Coordination: Heterogeneous swarm control

Reconfiguration
Control: self-reconfiguration

Metamorphosis from Four legged walker to a line

Left: MTRAN (AIST); Right: ATRON (K. Stoy et al.)
Control: self-reconfiguration
Control: from individual units to colony

Exploration

Coordination

Reconfiguration
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4. Scenarios
Scenario I: harsh terrain exploration

Scenario II: cave exploration

Scenario III: resources harvesting

Scenario IV: infrastructures building
Scenario I: harsh terrain exploration

Scenario II: cave exploration

Scenario III: resources harvesting

Scenario IV: infrastructures building

All images are the property of their respective authors (NASA, JAXA, Misc.).
Scenario I: harsh terrain exploration

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Scenario I: harsh terrain exploration

Scenario II: cave exploration

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Scenario IV: infrastructures building

- Mining
- Sampling
- Electricity harvesting
- Communication
- Adapative shelter
Conclusion

• Novel concept of robotic satellites:
  • Increase in robustness and versatility
  • Multi-target missions
  • Upgradable and reusable hardware
  • Lower cost

• Full robotic ecosystems for space exploration and colonization
The future is now!

Thank you for your attention

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