Modular Robot Design and New Module Creation

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Abstract

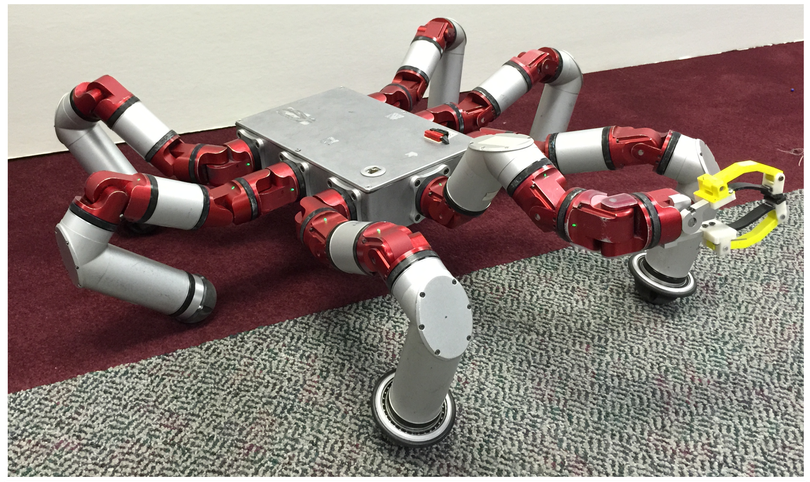
Robots have become an integral part of modern life as explorers, manufacturers, assistants, and laborers, and their uses and abilities continue to expand with each iteration and new design. Modularity allows a robot to be made up of smaller, more specialized, self-contained modules, which can be used independently or attached together to form a coherent robot that is able to perform an array of useful tasks. Though each configuration of modules is just as specialized as a non-modular robot, it is the ability to disassemble and reassemble the modules that is the key to truly versatile robotics. Aside from reconfiguring existing modules, the versatility of modular robotics can be expanded by the creation of new types of modules with different attributes or behaviors. The Biorobotics Lab has designed and implemented a modular robot architecture that can be reconfigured into bio-inspired robots such as the Snake Robot and the SnakeMonster hexapod robot. The goal of this research was to expand the module library by creating a new Torsional Module to enable new work to be done with each robot in the Biorobotics Lab.

The Modular Snake Robot

Pictured below is the Modular SEA Snake, a robot built out of 16 identical Rotary Modules that each provide one degree of freedom to enable bio-inspired snakelike motion.

Series Elasticity

The modules that make up the SEA Snake include a unique Series Elastic Actuator (SEA), which allows the modules to perform force sensing and built-in mechanical compliance. This is accomplished by placing an elastic element, such as a spring or rubber disk, in series before the output shaft of the module such that external forces on the module deflect the spring. This deflection is measured as a differential between two encoder values and used to determine the force given a known displacement and spring constant.



Reconfigurable Modular Hexapod

Robots that use this modular architecture are easily reconfigurable, as demonstrated by the SnakeMonster robot, a spider-inspired walking robot that can be adapted to different tasks easily. Here it is pictured with an arm and manipulator attached.

Specialized Modules

The abilities of each robot can be enhanced further with the creation of modules with specialized functions. These modules can be static such as the structural joints on SnakeMonster, actuated like the driven Tread Module, or sensor modules such as the camera head of the Snake Robot.

Actuated Modules

- SEA Rotary Module (pictured above)
- Tread Module
- SEA Gripper Module
- SEA Torsional Module

Sensor Modules

- Snake Camera Head Module
- Snaser Head Module
- Pressure Sensing Foot Module

Static Modules

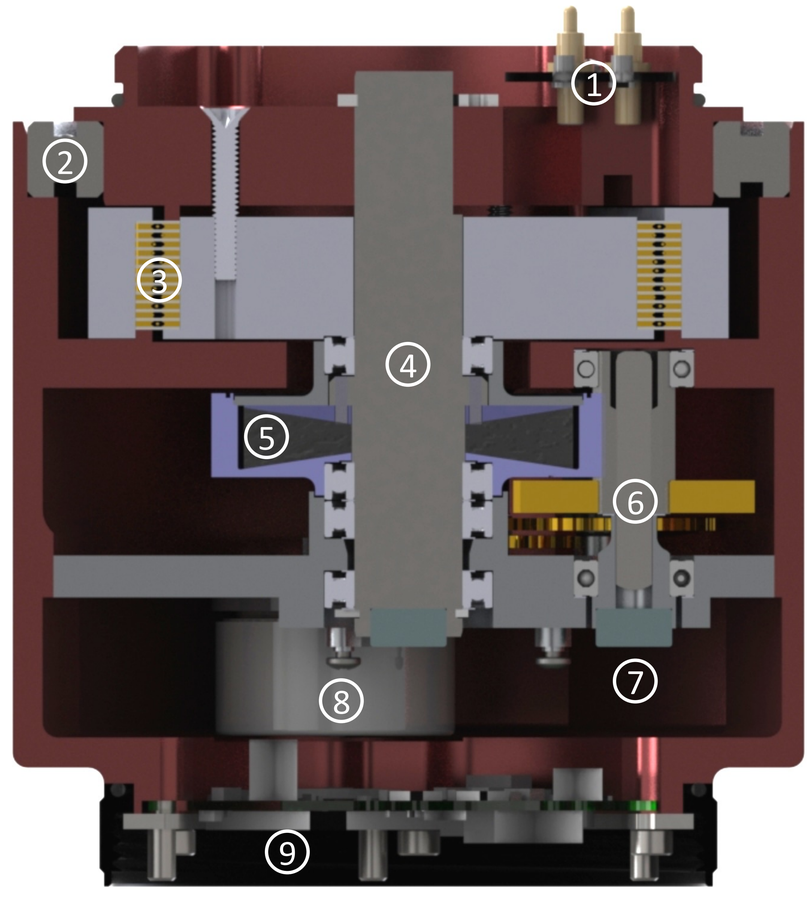
- Passive Wheel Module
- 90° Joint Module
- Clocking Module
- Adjustable Length Module
- Snake Tail Module

SEA Torsional Module

A large portion of this project was expanding the module library by creating the SEA Torsional Module, capable of a twisting degree of freedom while retaining the Series Elasticity of the Rotary Modules. This module can be used as a wrist for a modular arm, a shoulder joint for the SnakeMonster, or to decouple the motions of the front and back halves of the Snake Robot. The module design includes the electro-mechanical interfaces for use with other modules, a drive train with a series elastic element, and a custom slip ring.

SEA Torsional Module Cross Section Reference

1) Distal Module Interface
2) Locating Bearing
3) Custom 12 Channel Slip Ring
4) Main Output Shaft
5) Series Elastic Element
6) Gear Train, Geared Down 370/1
7) Dual Magnetic Encoder
8) Maxon Custom-Wound Motor
9) Proximal Module Interface



Conclusion and Future Work

The SEA Torsional Module design was completed and tested with a 3D printed prototype. The module was able to function correctly with all standardized module software and firmware and perform position, velocity, and torque estimation. Manufacturing and implementing the module on the robots is currently in progress, with potential future variations of the module likely. New specialized modules, such as the Actuated Extender Module and Viper Head Module are being researched and added to the module library, which will be accompanied by extensive software for simulating and visualizing the robots. These new tools and modular building blocks in concert will expand the functional versatility of the robots of the Biorobotics Lab.