An Open-Source Multipurpose Modular Robot

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INTRODUCTION

The concept of modularity is adopted when simple identical modules are used to build linkages in order to realise versatile robots that can support multiple modalities of locomotion, manipulation and perception. From a mechanical point of view, even if it is not the most efficient design approach, modular robotics still meets the requirements of standardization, modularization, extendibility and low cost [1]. From a design point of view, rapid-prototyping can be beneficial when developing modular robots with different configurations and for different applications. Development time and production cost can be significantly reduced. Therefore, rapid-prototyping is a necessary step to validate the design before making a physical prototype.

In order to give researchers a modular option that is inexpensive, easily customizable, and fast to fabricate, a novel highly adaptive multipurpose modular robot is introduced in this work for rapid-prototyping applications. The design of the fundamental building module follows the principle of minimalism to make the robot inexpensive, easily customizable, and fast to fabricate. Each module is equipped with the simplest mechanical structure, the minimum number of actuators (only a single actuator) and the simplest set of sensors. Thanks to the novel layout, Fused deposition modeling (FDM) manufacturing technology can be used to print each module, thus making the rapid-prototyping process very economical and fast. A new self-locking mechanism allows for connecting the modules in a very reliable way. Specially designed electrical contacts are embedded in the new self-locking mechanism allowing for easily powering each module.

The concept of the rapid-prototyping approach is combined with the modular concept makeing it possible to model different configurations for both grasping and locomotion applications. Both modular grippers or snake-like robots can be built. Different control algorithms can be implemented for the models. A low-cost sensing approach is used to realise functions for torque sensing at the joint level, sensitive collision detection and joint compliant control. The concept of modularity is also applied to the system architecture on both the software and hardware sides. In particular, a master-slave communication pattern is adopted: each module is independent, being controlled by a separate controller board, which can operates either as a master or a slave unit according to the application scenario.

The authors intend this work to be the first in a series of open-source designs to be released, and through the contributions of the open-source user community, result in a large number of design modifications and variations available to researchers.

BACKGROUND

Concerning modular robotic hands, our preliminary studies started by considering the design of modular grasping grippers capable of adapting to different requirements and situations. In [1], an iterative algorithm that allows for finding a trade-off between a simple gripper model and more complex human like manipulators was presented. However, the focus of this particular study was more on the algorithm perspective. Later on, ModGrasp, an open-source virtual and physical rapid-prototyping framework that allows for the design, simulation and control of low-cost sensorised modular hands, was presented by our research group in [2, 3]. However, the fundamental building module used in this work is made by two metal brackets that are not quite easy to fabricate for the user. The manufacturing process could be simplified by using a 3-D printing approach. This same idea was used in [4], where Raymond et al. presented a modular, open-source 3D printed under-actuated hand. The hand can be created through fast and commonly-accessible rapid-prototyping techniques and simple, off-the-shelf components.

Considering modular locomotion applications, the locomotion capabilities of snake-like modular robots were analysed in [5]. Different gaits have been implemented and tested on a real snake-like robot composed of eight Y1 modules. The Y1 module is a very inexpensive and easy to build module. It only have one degree of freedom, actuated by a remote control (RC) servo. There are two connection surfaces for attaching another modules that requires screws. Later on, the RepY1 module, a 3D-printable version of the Y1 module was designed, and used to build a snake robots that combine three capabilities: locomotion, climbing and grasping [6]. However, even if the RepY1 robot can be easily fabricated by using a commercial 3D printer, it still requires the use of screws and wires to connect one module to another, thus not allowing a very fast rapid-prototyping process.

To the best of our knowledge, a 3D-printable highly adaptive multipurpose modular robot that features a self-locking connecting mechanism and can be used to apply a rapid-prototyping approach to both grasping and locomotion applications has not been released yet.

DESIGN PRINCIPLES

In the design of the new module, a minimal number of 3D printed components and unmodified off-the-shelf parts are used, powered by a readily available, self-contained servo. The following principles are adopted:
- Principle of minimalism;
- Principle of symmetry;
- Self-locking mechanism.

As a result of the previously listed principles, the new module features the following characteristics:
- Easy assembling and disassembling;
- Easy wiring;
- Easy to add sensor;
- Easy to add cover (smooth enough if swimming);
- The cross-section should be square. (If possible, the edges can be extendable).

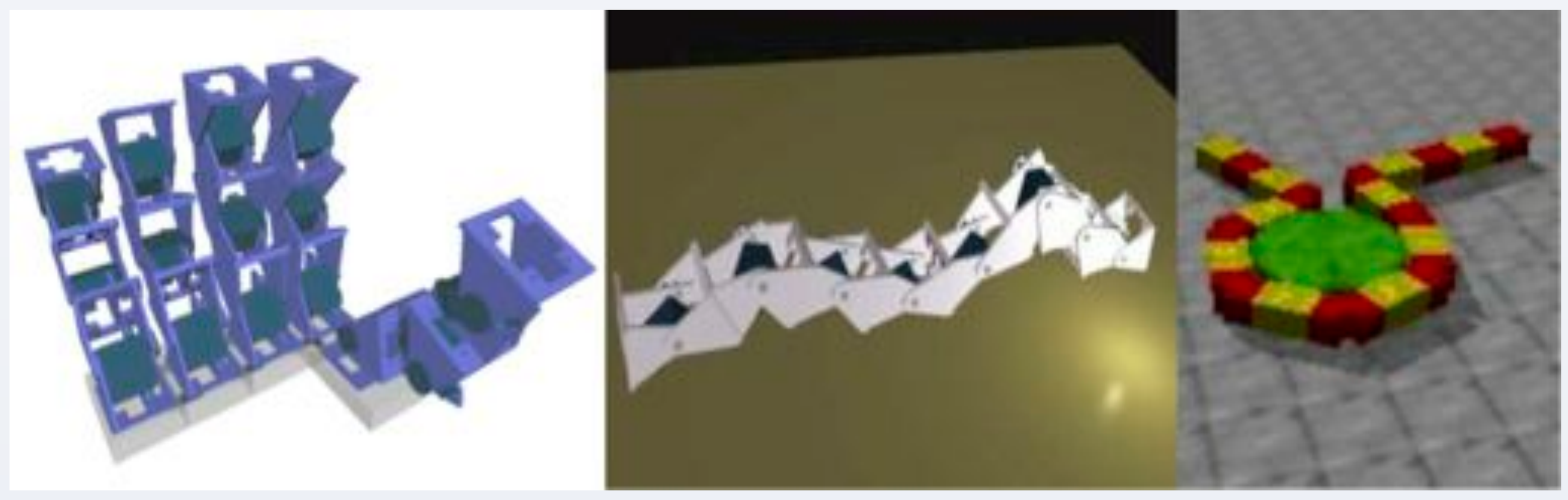

Fig. 1 The layout of the new module makes it possible to model different configurations for both grasping and locomotion applications. Hybrid functionality can be also achieved.

Fig. 2 The new self-locking concept mechanism allows for connecting the modules in a much more reliable way. Specially designed electrical contacts are embedded in the new self-locking mechanism allowing for easily powering each module.

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