Muscle Actuator Based on Electromagnetic Waves

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In this work, we present the design and fabrication of a biologically inspired soft robot which is capable of propelling itself through actuation of a flexible structure, similar to a real underwater fish. Actuation is essential for artificial machines to interact with their surrounding environment and to accomplish the functions for which they are designed. Over the past few decades, there has been considerable progress in developing new actuation technologies. However, controlled motion still represents a considerable challenge for many applications and development of advanced robots, especially at small length scales. Several approaches are reported in the literature based on optogenetics or electrical stimulation but which has limitations such as non-linearity and biocompatibility issues related to the wire bonding necessary to supply the actuators with the necessary excitation signal. Therefore, methods for obtaining controllable actuation is a key task to be further developed and constitutes the main motivation of our work which is based on applying electromagnetic wave theory to this area.

One potential solution to achieve efficient actuation of mini-biomedical devices (larger than 1 mm) and micro-devices (below 1 mm) is to exploit biological systems to construct biohybrid robots. This approach has the potential to be an exciting new paradigm and is based on the integration of properly engineered artificial structures and living bio-systems. In this work, we describe the design features that underlie the operation of the proposed robotic fish. These features include: 1) a unique controllable bio-actuator using electromagnetic waves which is referred to as 3D-bioprinting of engineered biocompatible hydrogels, 2) scaffolds for cells like carbon nanotubes–methacryloyl gelatin (CNT-GelMA) and 3) seeded biological components/cells such as cardiomyocytes cells (muscle cells that, when grown in contact with each other, couple to form an electrically integrated syncytium and contract as a coordinated unit) and 4) flexible power transmission system.

A radio-frequency (RF) circuit is hence designed in order to wirelessly transmit power from the excitation coil which is directly printed on a Petri dish, to the receiving coil directly embedded in the actuator and capable of receiving the required power to excite the soft robot through encapsulated microelectrodes. The power received by the device when embedded inside the lossy medium, is measured for 5 days at four different frequencies from 0.5 Hz to 3 Hz. All the components of the wireless power and control system embedded in the muscle actuator are fabricated through ink-jet printing on a flexible polymeric substrate in order not to impede the contraction of cardiomyocytes seeded on the surface i.e., the actuation dynamics.