Literature Review

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1 Soft Robotics

1.1 Context

Soft robotics is a relatively new area of study and development in the field of robotics. Soft robots differ from traditional hard robots in that they consist of components that are much more compliant and pliable in nature. Additionally, where hard robots generally have joints at which locomotion occurs with rigid sections in between, soft robots generally have fixed joints with the sections between causing the locomotion [1].

There are many benefits of soft robots over hard robots, such as increased safety around humans. Where hard robots are heavy, rigid, and often move with great speed and force, soft robots are generally much lighter, more pliable and as of yet, do not move with dangerous speed and force. Not only does this make them safer around humans, but also more ideal for working with fragile objects and materials. They also require lower tolerances for accuracy in manufacturing and usage, as by their nature they are less precise. Contrastingly, hard robots require much higher tolerances in their design and manufacture, as there is little room for error in their motions. They are also generally lighter than hard robots of a similar size, which could be useful in many cases [1].

1.2 Actuators

Actuators are components that cause controlled motion, generally used in robotics and machinery [2]. There are currently a few prominent types of soft robot actuators in use [3].

1.3 Types Of Actuators

Shape Memory Alloys (SMA) are metallic alloys that can be formed into a certain shape above a specific transformation temperature, and then reformed into another shape below that temperature. When the material is heated above the transformation temperature again, it reforms into the first shape, and if the temperature is lowered, it will recover the other shape. This property is the result of the transition between the martensite phase of the material at the lower temperatures, and the austenite phase at the higher temperatures. In SMA actuators, heating is done by applying a current directly to the material. SMA actuators are small, lightweight, have a high force-to-weight ratio, and are silent. In a straight shape they can exert powerful forces but only achieve small displacements relative to their length. When coiled they can extend much more but exert smaller forces. [4]

Shape Memory Polymers (SMP) are similar to SMAs, but where SMAs are generally comprised of metallic materials, SMPs are built from smart polymers. They have same shape memory property as SMAs. The initial shape is determined and obtained during the manufacturing of a particular element. Most current SMPs also use a temperature transition as the transformation mechanism. The element is then cooled and formed into another shape. When this shape is heated above the transition temperature, it reforms into the original shape, and when it cools down it returns. SMP actuators may use electricity or light as a heat source [5]. They have high deformation capacity and shape recovery. They are also much lighter, cheaper, and easier to produce than SMAs. However, they are generally limited in size, as they have low recovery stresses [6].

Dielectric/Electrically-Actuated Polymers (DEAP) use layers of polymers interspersed with conductive material, which, when provided with an electrical input, cause a chemical reaction that results in a volume change across the layers. The layers then bend in a particular direction. DEAPs are low on energy consumption, weight and noise production. They are also biocompatible and can work underwater. Their properties make them well-suited to mimic the traits of natural muscles. However, their reactions under higher voltages are not entirely understood yet and modelling them accurately is a complicated task [7].

Electro-Magnetic Actuators (EMA) make use of magnetic microparticles in a polymer matrix, which are then manipulated to cause motion by an external magnetic field from an electromagnet. This allows for a wide range of motion by simply varying the orientation and magnitude of the magnetic field. The actuators are typically small with good power efficiency and require relatively low voltages. They have quick response times and high dynamic ranges. They are, however, still in the early stages of development [8].

Lastly, Fluid Elastomeric Actuators (FEA) use soft polymeric structures with internal geometry that causes predetermined motion when driven by fluidic pressure. The fluid pressure may originate from high pressure containers or chemical reactions. They are relatively simple to design, produce, and control, and are lightweight and potentially inexpensive. By their nature, they can easily be scaled to multiple different sizes, and are resistant to many forms of damage [9; 10].

1.4 Shapes Of Actuators

(linear extension and resulting motion and application)

(torsional extension and resulting motion and application)

FEAs can be structured to curl on contraction and straighten out on expansion. This motion is similar to natural muscle contraction, and has a range of applications, especially when used in conjunction with multiple actuators. One use is as a gripper, where multiple FEAs of this type are arranged similar to the structure of a hand or a group of tentacles, with all curling inward. This gripper structure may then be used to pick up and manipulate objects, or hold on

(insert diagrams)

2 Soft Robot Modeling

2.1 Modeling Approaches

(discuss voxels and mesh)

2.2 Modeling Software

(discuss available software)

3 Evolved Virtual Creatures

3.1 Evolutionary Algorithms

(discuss evolutionary algorithms in general)

(discuss lindenmayer systems)

Evolutionary algorithms are of no use if there is no measure of performance. Each generation needs some metric to be tested against. In the context of virtual bodies, a physical target is often set, such as distance travelled in a certain direction within a limited time frame. Additional measures of fitness may also be applied, such as the energy requirements, size, and complexity of the resulting body. Thus bodies that perform well against these targets and metrics may be favoured for surviving or procreating, depending on the evolutionary algorithm chosen [11; 12].

An interesting phenomenon that is often prominent when working with evolving virtual bodies is that of emergent properties. Complex behaviours that are usually not well understood initially, arise from the combination of simple elements and rules. With evolving bodies, this may be illustrated by the elements, e.g. muscles, bones, joints, and the rules, e.g. motion limits, interaction between elements, which are relatively simple at first, resulting in complex organisms with methods of motion and behaviours that are not well understood without in-depth analysis [13]. This is desirable, as a goal of evolving virtual bodies is to arrive at designs that are original, unique and perhaps even not possible to be conceived of by the human mind, at least easily [11].

3.2 Previous Attempts

(discuss previous attempts)

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