Biomimetic Design of a Multi-Layered Dust Protection System for Optical Instruments Operating in the Lunar Environment

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Abstract

A method of identifying biologically meaningful keywords not obviously related to engineering keywords was developed to enhance discovery of relevant biological analogies for design problems. This paper reports the use of biologically meaningful keywords to identify biological analogies to generate solutions for protection required during lunar exploration. In lunar exploration, dust poses a significant problem due to its pervasiveness, adherence, and abrasiveness, causing premature failure of space suits and mechanisms. In this paper, biomimetic concepts are developed to protect a laser/telescope system. The resulting design is comprised of two subsystems. An antagonistic bending Shape Memory Alloy (SMA) actuator system, inspired by bivalves (a class of molluscs that include scallops, clams, oysters and mussels), is used to control the opening and closing of a two-piece lid system, while a high-voltage DC field generator prevents charged dust particles from approaching the optical surfaces. Preliminary results indicate that the SMA actuation system is capable of greater than one-hundred repeatable lid-opening and closing cycles. In addition, the high-voltage DC field was capable of controlling and deflecting 98% of incoming charged polystyrene particles (D_{mean} = 1 mm) away from a representative surface. The method of using biologically meaningful keywords to identify analogies was successfully applied in this case and could be applied in a variety of settings to generate useful solutions.

1 Introduction

The benefits of emulating biological phenomena in engineering design are demonstrated by many successful biologically inspired products. Approaching engineering design problems from a biological perspective often results in a more thorough investigation of solutions, including those often neglected by more traditional design approaches.

In this paper, we first summarize relevant work on biomimetic design. Next, we describe the design problem of protecting a LIDAR (LIght Detection And Ranging) system against lunar regolith (dust), which poses a significant problem due to its pervasiveness, adherence, and abrasiveness, causing premature failure of space suits and mechanisms. The use of biologically meaningful keywords to identify relevant analogies is then demonstrated for the lunar regolith problem. Finally, a prototype developed based on selected analogies is described and tested.

2 Related Work

Previous work on biomimetic design involved searching natural-language text for instances of engineering keywords that describe the desired function of design solutions. However, searching for instances of engineering keywords in biology texts is not always productive, as the language used between the domains of biology and engineering are sufficiently varied. Consequently, a method of identifying biologically meaningful keywords not obviously related to engineering keywords was developed to enhance discovery of relevant biological analogies for design problems [1][2].