2104 EFRI Abstract

Daniel McConnell Aukes

While the promise of printable, popup, and self-folding robots is being demonstrated through innovative designs and new manufacturing methods, the practical aspects of design are limiting the development process of such devices. Traditional three-dimensional CAD workflows are cumbersome for generating two-dimensional geometries of layered composites, requiring an intimate knowledge of the PCMEMS manufacturing process to ensure a successful, manufacturable design. Because the manufacturing rules of this new paradigm are still mostly internalized by the designer during the design process, errors are frequent, requiring more design iterations and restricting the pool of designers to experts.

To facilitate faster prototyping and development of printable, popup, and self-folding devices, we have developed a design tool called popupCAD. By building this design tool around the specifics of the layered manufacturing PCMEMS paradigm, we hope to speed workflow by encouraging design methods which are inherently manufacturable. The object-oriented structure of designs produced with popupCAD has the potential to reduce design flaws by encouraging modularity, reusing successful components rather than requiring designers to redraw them.

By encapsulating knowledge of the different functional layers' material properties and functional characteristics, popupCAD can help build intuition into manufacturability, kinematics, stiffness, and dynamics of the robots designed. This is accomplished via a suite of analytical tools built into the software. We hope that this analysis suite will give designers more immediate comparisons across differing design strategies, reducing the number of physical build iterations required.

PopupCAD's manufacturing analysis suite is presented in detail, providing a fundamental understanding of the design steps required to manufacture any device. With the goal of outputting a full manufacturing roadmap for any design, consisting of the output files required to cut and laminate the design as well as a human-readable set of process instructions, tailored to the needs of each design, we introduce the fundamental algorithms required to understand whether such a design can be cut, assembled, and removed efficiently.

The structural analysis feature, a work in progress, is inspired both by finite element analysis and standard robotic kinematic analysis. Printable, self-folding robots contain kinematics often found in origami-like devices, and are not necessarily stiff enough to be analyzed using ideal methods. We present techniques for analyzing such folded, hinged composite structures in a uniform way which takes such non-idealities into account. This framework accommodates the possibility for incorporating arbitrary assembly or actuator forces at the joints, enabling the analysis of closing order during assembly or output motion when actuated.

Finally we present several exemplar designs produced with popupCAD, highlighting the workflow, analysis tools used, and manufacturing process required to produce these designs.