An Automated Approach to Generating Novel MEMS Accelerometer Configurations

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(oral presentation)

Currently, the design of new MEMS devices is born from knowledgeable engineers with a keen understanding of electrical engineering, mechanical engineering, and the limitations imposed by the manufacturing process. Key features in various successful designs have become the repertoire from which future MEMS devices are created. For example, one of the most commercially successful MEMS devices today, the ADXL accelerometer (see schematic in Figure 1) developed by Analog Devices, Inc. (1998), makes uses of electrostatic comb-fingers, thin beams, and a monolithic suspended plate mass to make a successful accelerometer that surmounts conventional macroscopic designs.

The complete design problem of making functional accelerometers requires many goals and constraints, including the details of the corresponding circuitry and the manufacturability constraints. However, the basic difference in the variety of accelerometers made by Analog Devices is in the dimensioning of the accelerometer. By changing spring stiffnesses, mass size and comb finger lengths, different acceleration ranges can be achieved. The previous work of Mukherjee et al. (1999) and Zhou (1998) made strides in automating the dimensioning of components of an ADXL-style configuration so that custom accelerometers can be automatically designed to specific demands.

In this research project, a design automation technique known as A-Design (Campbell et al., 1999, 2000) addresses a greater challenge. A-Design is an “invention machine” that has shown to create novel configurations for electromechanical design problems where a predetermined configuration is unknown. In this work, the computational technique develops new accelerometer configurations without prior knowledge of the ADXL configuration. While one can see obvious advantages of the ADXL design, it is possible that other, possibly better, configurations exist.

The A-Design methodology combines innovations from artificial life, genetic algorithms, stochastic optimization, multi-objective optimization, qualitative physics, and asynchronous teams. The algorithm is founded on optimization techniques but further incorporates software agents with an adaptive search for new design solutions. In order to create novel accelerometer configurations, the A-Design requires three types of information. First, a library of components or discrete elements is needed to build designs. In the case of constructing surface-micromachined MEMS accelerometers, this includes beams, plates, and anchors. Second, a description of the inputs and outputs provide the scope for the design process. Here, the input is an acceleration, and the output is a voltage proportional to the input magnitude. Finally, the A-Design system requires metrics or objectives to optimize in order to guide the search process. These metrics for the accelerometer problem include minimizing area, maximizing sensitivity, maximizing
the maximum acceleration and minimizing movement of the proof mass in the orthogonal direction to sensing. In order to evaluate these objectives for each candidate that is searched by the automated design process, an external simulation package (SABER, Analogy, Inc., 1995) is tied to the optimization process.

The results of the A-Design design process (examples shown in Figure 2) show some initial promise for both future design synthesis of MEMS devices and for the effectiveness of the A-Design algorithm. Currently, the final design states show some significant deficiencies when compared to the ADXL layout. However, with better analysis, the inventive power of the process would ideally lead to more useful designs. Future work in this area includes improving the automated analysis invoked by A-Design, the inclusion of design rules based on manufacturing constraints, and the application to new MEMS design problems.

Figure 1: The most successful surface micromachined accelerometer configuration is comprised of a proof mass, beams, and anchors.

Figure 2: Three new configurations created by the automated design synthesis algorithm, A-Design. These are likewise construct from masses, beams and anchors (numerous small beams make up the comb fingers shown as black lines).
References


