Abstract

Microelectromechanical systems (MEMS) have been popular in recent decades, with large systems being converted into small chips and portable devices. Due to their compact size, low cost, and other advantages, these devices find applications in a wide variety of fields, including aeronautics, biological science, telecommunications, automobile industry, etc. Here in this thesis, the two most used MEMS devices (MEMS thermoelectric energy harvester and electrothermal microgripper) are modeled. Like most MEMS devices, thermoelectric energy harvester and electrothermal microgripper are modeled as distributed parameter systems with partial differential equations. The finite element method converts these partial differential equations into a large number of ordinary differential equations making the entire procedure computationally expensive. Model order reduction (MOR) reduces the computational complexity of such systems. It produces lower order approximations of such large scale systems, preserving the characteristics of the large scale system.

To come up with an adequate design, a complete understanding of the relationship between the structure, materials, and performance of the device is required. If this parameter dependence can be retained within the reduced models, the large-scale system does not have to be synthesized and reduced repeatedly for each parameter value. This idea gives rise to parametric model order reduction (pMOR).

It has been observed that when geometric parameters are changed, the finite element meshes, the size of the models or the dimension of system matrices change invariably. Popular pMOR methods become inapplicable in such cases. This thesis proposes a new finite element compatible matrix interpolation for pMOR for handling such problems. It is applied to the thermoelectric generator system and microgripper system. This method is also applied to the microgripper system considering multiple parameters.

While designing, most design methodologies obtain the optimum value of the parameter by comparing the data obtained through testing or device responses without considering optimality. An efficient design of the microgripper is achieved here. The Sine Cosine Algorithm, a population-based optimization algorithm, is employed to obtain a desirable solution for optimizing the design parameters of the microgripper. Following that, an averaging process is carried out to propose an efficient design procedure.

Not only design parameters but also the generated heat of the device has an impact on the performance. The electrical conductivity of gold changes nonlinearly as the produced heat of the system changes, making the electrothermal model of the microgripper system nonlinear. Again, as the produced heat changes, the SU-8 polymer's elastic properties vary nonlinearly, and as a result, the thermo-mechanical system becomes nonlinear. Nonlinear model order reduction methods such as POD-DEIM and POD methods are applied to reduce the computational complexity of the system.

Keywords: Micro-Electro-Mechanical Systems (MEMS), Thermoelectric Generator (TEG), Electrothermal Microgripper, Finite-Element Method (FEM), Parametric Model Order Reduction (pMOR), Sine Cosine Optimization (SCA), Nonlinear Model Order Reduction