WCSMO10 Abstract (draft 13/01/08)
September 15, 2012 to January 15, 2013

Shape optimization of electrostatic capacitive sensor

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Abstract

Electrostatic capacitive sensor is used in many devices such as computer displays, smartphones, tablets and others. The function of the capacitive sensor in those devices is to detect fingers of human body that has a dielectric constant different from that of air.

The present paper shows how to construct a shape optimization problem for the capacitive sensor to maximize the function and how to solve the problem.

We define two main problems. One is a basic electrostatic field problem consisting of sensing electrode, shielding electrode and air. The basic electrostatic field problem is constructed using the Laplace equation for electric potential in the domain of air. The sensing electrode and the shielding electrode are considered as the Dirichlet conditions. The other is an electrostatic field problem adding a finger to the basic electrostatic field problem. The finger is introduced as the Dirichlet condition.

Using the solution of the two main problems, we define the difference of the electrostatic energies of two main problems as an objective cost function. In addition, the volumes of the sensing electrode and the shielding electrode are used in cost functions of constraint conditions.

The shape derivative, which is defined as the Fréchet derivative with respect to domain variation, of the objective cost function is evaluated by the adjoint variable method. Since in the present shape optimization problem, the two main problems are defined, we obtain two adjoint problems corresponding to the two main problems. Using the solutions of the two main problems and the two adjoint problems, we obtain the theoretical result of the shape derivative of the objective cost function.

To solve the shape optimization problem to maximize the difference of the electrostatic energies of two main problems with volume constraints of the sensing electrode and the shielding electrode, we use an iterative algorithm based on the H1 gradient method. In H1 gradient method, domain variation is obtained as a solution to a boundary value problem of an elliptic partial differential equation, such as a linear elastic problem, defined in the domain of main problems using the Neumann condition with the negative value of the shape derivative on the boundary. The volume constraints are satisfied using the KKT conditions in the shape optimization problem.

We developed a computer program to solve the shape optimization problem based on the iterative algorithm by using commercial software as solver to the boundary value problems. Numerical example is going to be shown in the WCSMO-10.