Finite Element Method and Genetic Algorithm for MEMS Analysis

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ABSTRACT

This paper presents an analysis of the finite element method (FEM) and genetic algorithms for the MEMS analysis and BIOMEMS design. The finite element method is the method used for the computational analysis of mechanical structures in MEMS, BIOMEMS, among others. However, the FEM presents a major drawback: the generation of mesh does not meet any criterion optimization, which in turn prevents ensure the best possible reproduction of the structure to analyze. Genetic algorithms are a particularly robust computational method, which have demonstrated their ability to solve problems where optimization requires adjustment of a large number of parameters (multivariate) even when they are not competing performance indices (multiobjective). In addition, in order to improve the process, it can be a good way to educate mechanics computational applications in MEMS, and an example of this is used by the American company ARGOR©.

Keywords: Finite Element Method (FEM), Genetic Algorithms, MEMS, Optimization.

1 INTRODUCTION

The FEM is a very general numerical method for solving differential equations used in various engineering and physical problems. The method is based on dividing the body, structure or domain (middle continuous) on which are defined certain integral equations that characterize the physical behavior of the problem in a number of subdomains not intersectantes each other, so-called finite element. The finite set of elements form a partition of the domain also called discretization. Within each element, there are a number of points representative called nodes. Two nodes are adjacent if they come at the same finite element, plus a node on the border of a finite element may belong to several elements, all nodes considering its relations adjacency is called mesh [1].

In recent years, the international scientific community has shown an increasing interest in a new technique of artificial intelligence, based on the theory of evolution, known as evolutionary programming, in which the method that has proved most successful in real applications is the technique described as genetic algorithms. These are based on the selection mechanisms used by nature, according to which the fittest individuals of a population are those who survive to adapt more easily to changes in their environment. Today, we know that these changes are made as a result of a variation on information from genes of an individual (basic unit of encoding each of the attributes of an organism), and that their most desirable attributes (ie. which enable you to better adapt to their environment), transmitted to their descendants when it is reproduced sexually or asexual [2].

2 METHODOLOGY

2.1 Finite Element

In view of a closed enclosure the steps for the resolution are:

- To divide the enclosure in Finite Elements: Triangles (3 nodes), Tetrahedrons (4 nodes), etc.
- To deduce the equation 1. That describes the potential *f* inside an FE.
- To raise the equations that gives the conditions of adjustment of the solutions in the borders of the FE.
- To calculate the potentials in the nodes of every FE by means of some of the methods that then will be mentioned.
- To solve the algebraic raised equations. Generation of the finite Elements.
    a. The contours may be irregular
    b. The FE will be so small as the programmer considers it. At more changes in the potential; the FE will be smaller [3].

The Function of Energy is proposed:

$$E = \underbrace{\sum_{i,j}\left[p_{i,j,k} - x_{i,j,k}\right]^2}_{\text{data fidelity term}} + \underbrace{\lambda\left(\sum_{i,j,k}\sum_{i_s,j_s,k_s}\left(x_{i,j,k} - x_{i_s,j_s,k_s}\right)^2\right)}_{\text{enforces smoothness}} \qquad (1)$$

Where:

$p_{i,j,k}$ is a value of the voxel of the original image.

$x_{i,j,k}$ is the classification of this voxel.

$i_s j_s k_s$ represents the sweep of the voxel.

The energy is the numerical value of the total sum of distances entity both sets of voxels that intervene in the segmentation or rather the function of intensities [4]. In this case it is wanted to realize a record more detailed in all the images by what there will be defined in a vectorial field that can change point by point in the images.

We want to make a record more detailed when it will define a vector field which can vary point by point in image

$$E = \sum_{i,j}\left[p_{i,j,k} - x_{i,j,k}\right]^2 + \lambda\left(\sum_{i,j,k}\sum_{i_s,j_s,k_s}\left(x_{i,j,k} - x_{i_s,j_s,k_s}\right)^2\right) + \left[\lambda_x\ \lambda_y\ \lambda_z\right]\begin{bmatrix}\int_\Omega \left|\nabla u(p)\right|^2 d\Omega \\ \int_\Omega \left|\nabla v(p)\right|^2 d\Omega \\ \int_\Omega \left|\nabla w(p)\right|^2 d\Omega\end{bmatrix} \qquad (2)$$

Where coordinates updated in the image that is being transformed are:

$$E = \begin{bmatrix}\hat{x} \\ \hat{y} \\ \hat{z}\end{bmatrix} = \begin{bmatrix} x + u(x,y,z) \\ y + v(x,y,z) \\ z + w(x,y,z)\end{bmatrix} = \begin{bmatrix} x + \sum_{i=1,j=1}^{m} N_{i,j,k}(x,y,z)\,u_{i,j,k} \\ y + \sum_{i=1,j=1}^{m} N_{i,j,k}(x,y,z)\,u_{i,j,k} \\ z + \sum_{i=1,j=1}^{m} N_{i,j,k}(x,y,z)\,u_{i,j,k}\end{bmatrix} \qquad (3)$$

2.2 Genetic Algorithms

Selection of the population (individuals) is in the following way:

$$X = (x_1, x_2, x_3, \ldots, x_n) \qquad (4)$$

Where every x_i represents a gene of the chromosome, of the problem treated here [5], in this case each of the parameters describe the meshes of the Finite Element.

Crossover: The general procedure is:

- a probability of crossing establishes (pc), which determines the average quantity of individuals who will cross:. $pc\ x\ population\ size$
- For every member of the population (chromosome) a random number a is generated into the range (0, 1), if $a > pc$ the chromosome given for crossing is selected.
- For every couple (par) of selected chromosomes (parents) the arithmetical operator of crossing applies himself. If *c1* and *c2* are the chromosomes to be crossed, there will be generated two new members (children).

Mutation: there will apply him the operator of not uniform mutation, of agreement to the following general procedure:

- a probability of mutation establishes (pm), which will help to determine the average quantity of individuals who will be mutated:. $pm\ x\ population\ size$
- Every gene inside a chromosome has the same probability of being mutated, in such a way that for every chromosome of the current population (after the crossing) and for every gene inside every chromosome a random number is generated in the range of (0, 1).
- If $a < pm$ the corresponding gene mutates [6].

3 RESULTS

We show an example of a circular figure Mirror MEMS.

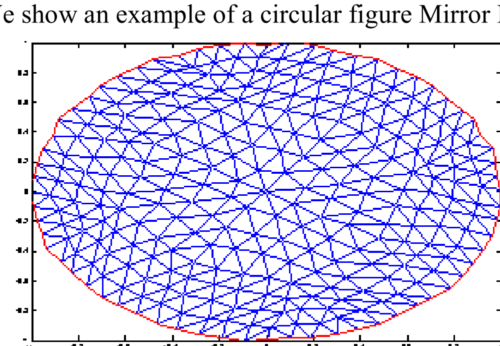

Fig. 1. Figure of a circular MEMS with FEM.

We will figure using an evolution with Genetic Algorithms.

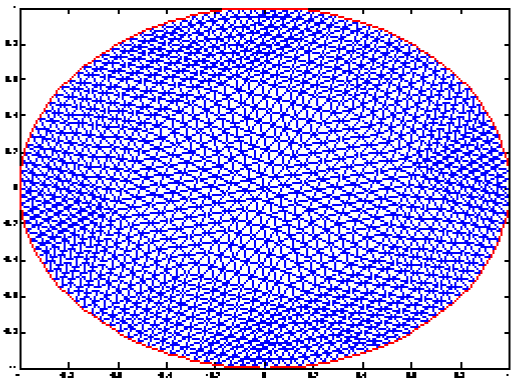

Fig. 2. Figure of a circular MEMS with a step of Evolution of Genetic Algorithm.

We obtain the polygonal description (Fig. 3), this step is useful to see the solution of the Partial Differential Equation (PDE) that describe the FEM (Fig. 4).

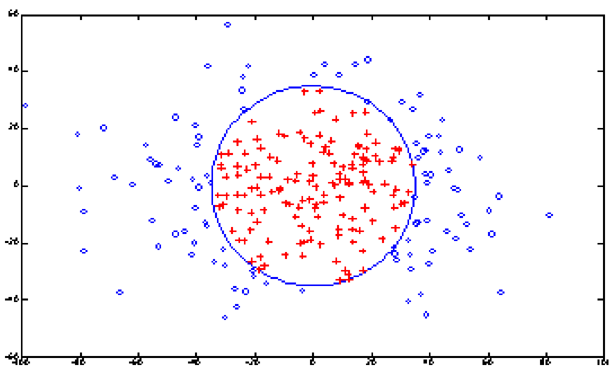

Fig. 3. Description Polygonal

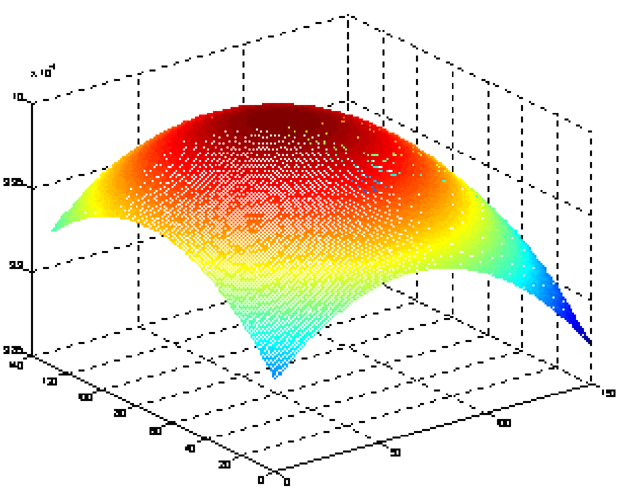

Fig. 4. Initial phase of PDE

Finally it is shown the total evolution of the GA for MEMS.

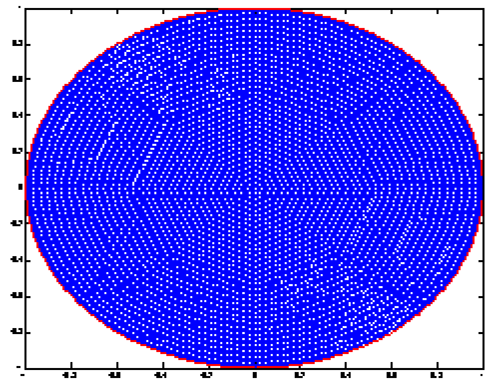

Fig. 5. Figure of a structure of circular MEMS with the complete evolution from Algorithm Genetic.

4 CONCLUSION

This paper presents a new method, physics-based deformable model. The model results from the minimization of a deformation field simultaneously satisfying the constraints of an elastic body and a local image similarity measured. The model provides a physically realistic deformation field and also allows us to inspect the characteristics of the deformed objects. This can be useful for the inspection of stresses induced by the deformation of certain objects on their surroundings, in our case the detection of MEMS.

In the experiments, the objects were considered to be homogeneous elastic bodies. Further improvements of the algorithm include the assignment of different elasticity's to the different objects represented in the image. This will require a preliminary segmentation of the objects to be deformed in order to be able to set appropriate elasticity coefficients to every cell of the mesh.

We would lack to design an algorithm that assures that the meshes are the best possible one (in the sense of the image representation), also to include one better area within the image, providing an improvement in the diagnostic supplied by the method suggested in this paper.

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