# PROBLEM SOLVING USING EVOLUTIONARY ALGORITHMS AND FINITE ELEMENTS METHOD

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Abstract: We describe an optimisation approach, which connects the modelling based on the Finite Elements Method with Evolutionary Algorithms. This approach makes it possible to optimise parameters in applications, which are described by partial differential equations as electromagnetic field, heat transfer, mechanical forces, aerodynamics and hydrodynamics, chemical reactions and others. Additionally the approach can be used for solving control design and optimisation tasks in the above mentioned application domains.

Keywords: Finite Elements Method, Evolutionary Algorithm, Optimisation, Heat Transfer, Hydrodynamic, Control

#### **3** Design of Optimal Hydrodynamic Shape

In this task the optimisation of the hydrodynamic shape of an object located in a pipe, which is overflowed by liquid is described [4]. The hydrodynamical resistance of the object should be minimised. That means, the turbulations should be minimised. The shape of the object is represented using a Besiere courve, which is defined in 4 control points (Fig.3) [7]. The GA finds the x and y coordinates of the 4 control points  $P_1, P_2, P_3, P_4$ . Each chromosome has 8 genes  $x_{p1}, y_{p1}, x_{p2}, y_{p2}, x_{p3}, y_{p3}, x_{p4}, y_{p4}$ . The cost function contains the liquid flow simulation (in FEM) and the calculation of the turbulation measure, which is in an integral form [7]. In Fig.4 the population of the 9th generation is shown and in Fig.5 the final shape of the object is shown.



Fig. 3: Obstacle in a pipe and its control points P1-P4 for the Besiere courve



Fig. 4: Population in the 9th generation of the GA



Fig. 5: Optimal shape of the obstacle in the pipe

#### **4** Optimisation of Heating Bodies

This application aims to design the optimal sizes and optimal locations of two heating bodies in a one-room house [5]. Consider the cold air flow in the external side of the house (Fig.6, 7 and 8). The red arrows show the air flow direction. It is

required that the internal temperature is  $19^{\circ}$  C and it is as homogeny as possible in the entire space of the room. For that reason 27 reference points are defined (Fig.6), which temperatures are considered in the cost function. The genetic algorithm is searching the optimal size (in coordinates x,y,z) and positions (in coordinates x,y; z=0) of the heating bodies. The cost function consists of two parts. The first part is defined as the difference between the 27 reference points and the required

temperature (292 K). The second part is the temperature dispersion of the 27 reference points. In Fig. 7 and 8 the final construction is depicted with the temperatures in the interior and also with the external air flow.

The simulation time of the FEM model in Comsol takes about 2 minutes, which represents for a single generation computation time of 60 minutes in case of 30 individuals. That means the computation time of the GA for this task takes hundreds of hours on a single PC.



Fig. 6: Referent points in the room



Fig. 7: Final location of the heating bodies in the room



Fig. 8: Final location of the heating bodies in the room, upper view

## 5 Conclusion

The aim of this contribution was to connect the Finite Elements Method with Evolutionary Algorithms for parameter optimisation purposes. In our case the program products Comsol Multiphysics and Matlab/Simulink has been used. The first application area are construction tasks, where the models of the optimised objects can be described by partial differential equations. Here the FEM model simulation is part of the cost function. The second presented area is the control design, where the FEM model is an alternative to ,,conventional" dynamic system models in form of transfer functions, differential equations as well as other approximations like Artificial Neural Networks. FEM is modelling the controlled object in the entire defined geometry, with all its non-linearities, boundaries etc.

The main disadvantage of the approach described above is the high computational effort required. For more complex applications the computation times on a single PC takes about hundreds even thousands of hours. From that reason, it is important to parallelise the computational task to more processors [2].

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