# Heating system designed by genetic algorithm

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#### Abstract

The contribution deals with the use of the genetic algorithm (evolutionary methods in general) for civil engineering problem solving. The genetic algorithm seeks the optimal size of a heating object in a 3D house, wich emphasis of desired comfort and temperature. The genetic algorithm was created in Matlab, the thermal simulation of the house under consideration of all construction materials is in Comsol Multiphysics and it is based on the finite elements method. The 3D model was created in Catia V5. In this article also the possibilities of utilization of evolutionary methods in complex design process of building subsystems are mentioned.

Key words: Genetic algorithm, 3D model, finite element method

## 1 Room (building) model

If we want to make simulation of simple or complex object, in the first step we need to have the model (some representation) of real object. From our point of view, we need 3D model, because we want to simulate physical actions in the space (in the building). 3D model can be created in various programs e.g. ArchiCAD, 3D Max, Catia V5 etc. These programs vary as in theirs "universality" as in resultant 3D model. For example, if we create model in ArchiCAD it is relative easy and fast, but the model size is very big and hard to use it in simulation software. (This problem can be circumvented if we import this model in 3D Max and by this tool we can eliminate all not needed texture and export the final model to VRML object). Mentioned problem does not have Catia V5. (Primarily in Catia engineers create models of machine parts, but we can easily use it for our purposes). The model created in Catia is precise and convenient for simulation.

## 2 Simulation

We can use this 3D model in various simulation software, which allow simulating a heat diffusing process in materials. We decided for program Comsol Multiphysics due to many advantages in comparison with the other programs. Comsol is a new version of former FemLab 3.3. As the name betray, the solving of physical process is based on FEM (Final Element Method).

This tool allows solving the task (in one step) from many physical aspects (e.g. temperature variation in dependence on electric current of conductor and the influence of this variation on mechanical conditions of conductor). Another advantage is its simple connectivity to MatLab and possibility to import 3D models from many programs, one of them is Catia V5. We just import model from Catia into Comsol and we save a lot of time, because the process of model creation in Comsol is not easy.

Before the launching of simulation we have to do next actions:

- to set properties of Sub-domains
- to set properties of boundary surfaces
- to create Mesh for FEM solver



Fig. 2b The definition of evaluating points GA (left), simulation (right)

## **3** Genetic algorithm

## **String**

Due to the fact that we are looking for only 3 parameters (dimensions of heating object, so it means height, width, thickness). The extents of these parameters are given by deployment this object in the room (e.g. the width of radiator cannot be longer than width of the room).

## **Population**

By GA we are looking for only three parameters, therefore is sufficient if the population has 10 terms. We decided to use selection by balanced roulette wheel with elitist property (the best individual goes to the next population without any change).

## Fitness

The quality of solution is considered from two criterions, for that reason fitness consists from two parts, which each is multiplied by balance coefficients. The first part of fitness is defined as a difference between average temperature (of 18 points) and given temperature (we set the desired temperature on 294 K i.e. 21 °C). The second part of fitness is defined as the sum of absolute values of difference between the specific point and average temperature. The second part is considerably bigger, so we multiply the first one with balance coefficient (val. 150) to reach the equal weight on fitness. This coefficient will be various from case to case according the part, which we want to emphasize.

## Parameters of evolution

GA uses one point crossing, additive mutation (max. value is 0.1) with the rate 0.25 and mutation on random value with the same rate (0.25). Rate is from interval  $\langle 0, 1 \rangle$  and this value represents the occurrence off mutations in the population.

#### Number of generation

Due to the fact that we are looking for only three parameters and the task is not so complicated, we set the stop condition of GA on 100 generations. As you can see (Fig. 3a left) this amount is sufficient. (The average temperature in room is 294.0168 K).

<u>The solution</u> (at the end of  $100^{\text{th}}$  generation)



Fig. 3a The progress of fitness (left), the simulation of the best solution (right)

#### Conclusion

On the simple example were showed the possibilities which allow mutual interconnection of MatLab and Comsol Multiphysics. By the genetic algorithm were found optimal dimensions of heating object, with fulfillment of prescribed conditions. The amount of parameters needed for simulation of more complex objects (e.g. heating system of whole house) grows considerable and also grows the time needed for one simulation in Comsol (for bigger objects we have bigger mesh, i.e. more points for FEM solver). If we consider also the building construction (thermal/insulation properties from the point of heating) the string length of GA will be count in tens. With the amount of parameters also grows the population of GA and the number of needed generations. If we assume that one simulation takes about few tens of seconds (on one processor unit) the resultant time for whole computation process can easily reach on few days (months). Therefore is necessary to involve only significant parameters. All in all if we want to reach the acceptable computing time of more complex solutions, is needed to use multiprocessor unit or net of computers.