A Hybrid Genetic Algorithm with Fuzzy Logic for Optimization Heat Loss in Spherical Reactor

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Abstract— Work's purpose is to ascertain the suitability of the fuzzy-genetic algorithm (FGA) methodology, introduced by two of the authors in previous papers [1, 2], for the optimization of mechanical complex components subject to several criteria and constraints. A genetic algorithm (GA) is hybridized with an artificial immune system (AIS) as an alternative to tackle constrained optimization problems in engineering. The AIS is inspired in the clonal selection principle and is embedded into a standard GA search engine in order to help move the population into the feasible region. The procedure is applied to mechanical engineering problems available in the literature and compared to other alternative techniques. A genetic algorithm (GA) is hybridized with an artificial immune system (AIS) as an alternative to tackle optimization problems in engineering. The AIS is inspired in the clonal selection principle and is embedded into a standard GA search engine in order to help move the population into the feasible region. The procedure is applied to mechanical engineering problems available in the literature and compared to other alternative techniques. FGA optimization results are arranged by an "ad hoc" MDL program, written by one of the authors, which automatically draws the 3Dimodel in Micro Station environment of the designer can directly visualize or plot a true scale picture of the solution for the problem considered.

Keywords: Introduction, FGA, Crossover, Procedure, Analysis of Heat Loss, Result

I. INTRODUCTION

This paper is part of a larger effort devoted by the authors to the development of computerized tools in assisting designer's activity.

Authors focused their attention on the preliminary phase of engineer's design activity where the most influencing decisions are assumed for the successive development of a project. First of all, a fuzzy design tool has been developed [3] to perform a rough component sizing and a sensitive analysis of the most influencing parameters for the design, by accounting for any objective constraint or for to the environment. The existence of these additional heat transfer resistances may alter the rate of heat transfer from the hot region of the reactor to the environment and hence the stability of the reaction. This work presents an initial numerical study of thermal explosion in a spherical reactor under the influence of natural convection and external heat transfer, which neglects the effects of consumption of reactant. Simulations were performed to examine the changing behaviour of the system as the intensity of convection and the importance of external heat transfer were varied. It was shown that the temporal development of the maximum temperature in the reactor was qualitatively similar as the Rayleigh and Biot numbers were varied. Importantly, the maximum temperature in a stable system was shown to vary with Biot number. This has important consequences for the definitions used for thermal pre-existing subjective experience of the designer. Then several component optimization programs have been written by the authors following different methodologies: genetic algorithms [4], fuzzy-genetic algorithms (FGAs) [1, 2].

When any exothermic reaction proceeds in an unstirred spherical cell, natural convection may develop. This flow can significantly alter the heat transfer from the reacting fluid to the environment and hence alter the balance between heat generation and heat loss.

In reality, there will be heat transfer resistances associated with conduction through the wall of the reactor and from the wall explosion in systems with significant reactant consumption.

Also, locales of parameter space where blasts happened were distinguished. It was demonstrated that diminishing the Biot number improves the probability of blast and decreases the balancing out impact of common convection.

Aim of the paper is the further verification of this latter methodology in mechanical component optimization through the connection of the mathematical modelling to a CAD straightforward visualization of the FGA results.

FGAs have been proposed to alternatively face some of the difficulties the classical optimization methods show in treating multi-objective and multi-constraint problems. Several standard approaches have been proposed in literature. One of those assumes a weighted global objective function summarizing, inside the same expression, optimization criteria.

II. FGA OPTIMIZATION

A brief description of the FGA methodology is given here (Fig. 1), while details can be found elsewhere [1].

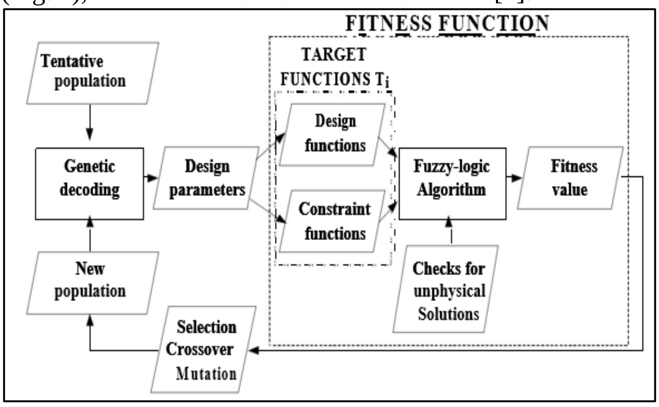


Fig. 1: Scheme of the fuzzy-genetic algorithm.

Each set of design variables identified in the optimization problem are suitably codified to represent a virtual individual (possible problem-solution string) of a genetic-algorithm virtual population. For each individual, the genetic algorithm derives the corresponding crisp values of the design and constraint functions (globally called, by the authors, target functions).

The new method, exposed in paper [1], consists in deriving the merit function (fitness) of each individual through a fuzzy logic algorithm, instead of utilizing the classical weighted objective function [7, 8]. Inside the fuzzy engine, the fitness and both the design and constraint functions (target functions) are transformed in linguistic variables (expressed through fuzzy numbers, [11]).

The fuzzy algorithm behaves like a controller and is composed of three major components: an input interface, an inference engine and an output interface [1, 6, 12].

1) The input interface (fuzzification module) performs a crisp to fuzzy transform of the target functions into linguistic variables (for details, see [6]).
2) Linguistic target functions are handled (inference engine) according to a heuristic rule base, suitably settled [1, 2], to obtain linguistic values for the linguistic fitness.
3) The output interface (defuzzification module) allows to derive the crisp output (the crisp value of the fitness) from the fuzzy output obtained during the inference phase, by applying the centre of gravity method or the height method [1, 6, 12].

Crisp fitness is, as usually, utilized by the genetic algorithm (selection, crossover and mutation, [13]) to improve the population of the solutions and to derive the near optimum suitable virtual individual (Fig. 1).

III. Crossover

Crossover is biological terms refers to blending of chromosomes from to parents to produce new Chromosomes for the offspring. The analog carries over the crossover in GAs. The GA select two string at randomly from the mating pool. If crossover does take place then a random splicing point chosen in a string. The two string are spliced and spliced region are mixed to create two (potential) string. The child string are placed in new population.

EXAMPLE- if the two string 10000 and 01110 are selected for crossover. The GA decide to mate them. the GA select splicing point of 3. Then new created string are 10010 and 01100 crossover performed untill the new population is created.

Old 1= 1 0 0 0 0
Old 2= 0 1 1 1 0
If crossover occurs then.
New 1= 1 0 0 1 0
New 2= 0 1 1 0 0

A. Procedure

1) Algorithm 1 the Hybrid GA Algorithm

1) HYBRIDGA(nGenGA,nIterAIS)
2) COMPUTEFITNESSVIOLATION(population)
3) for i = 1 : nGenerationsGA
4) DIVIDE(population,antibodies,antigens)
5) for j = 1 : nIterationsAIS do
6) CLONE(antibodies,temp)
7) MUTATION(temp)
8) COMPUTEDISTANCE(antigens,temp)
9) SELECTBETTER(temp,antibodies)
10) end for
11) UNION(antibodies,antigens,population)
12) TOURNAMENTSELECTION(population,temp)
13) CROSSOVER(temp)
14) MUTATION(temp)
15) COMPUTEFITNESSVIOLATION(temp)
16) CHANGEPOPULATION(population)
17) end for
18) end procedure

IV. Optimization Heat Transfer in Spherical Cell

The heat exchange coefficient or film coefficient, in thermodynamics and it is only depend on tem. And show total heat transfer and the thermodynamic main impetus for the stream of heat (i.e., the temperature difference, ΔT):It is utilized in figuring the heat exchange, ordinarily by convection or stage change between a liquid and a strong. The heat exchange coefficient has SI units in watts per squared meter kelvin: W/(m2K).The heat exchange coefficient is the equal of heat insulance. This is utilized for structure materials (R-value) and for dress insulation. There are various techniques for computing the heat move coefficient in various heat exchange modes, diverse liquids, stream routines, and under various thermohydraulic conditions. Regularly it very well may be assessed by separating the thermal conductivity of the convection liquid by a length scale.

If heat transfer in spherical cell by convection. Because hot & cold fluid flow in spjerical cell.

The rate of heat transfer due to natural convection is described by Eqn.

$$Q = h.A.(\Delta T)$$

Where –
If hot fluid temperature are denoted by (T1).
Cold fluid temperature are denoted by (T2).
Heat transfer coefficient (W/m2·K) are denoted by (h)
Area of spherical reactor cell are denoted by (A)

Thickness is no longer an effective way of describing how the heat is transferred. The heat transfer coefficient can be thought of as the inverse of the resistance to heat transfer. Also, because temperature is a function of distance(x) from a surface, the ΔT term is calculated between the surface and the bulk temperature of the liquid phase.

Heat transfer between a solid body and a moving fluid like as vapour and gas is governed by the Newton's cooling law:

$$q = hA(T_s - T_\infty),$$

where T_s is the surface temperature and T_∞ is the fluid temperature. Therefore, to increase the convective heat transfer (h), one can

– Increase the temperature difference (T_s-T_∞) between the surface and the fluid.
– Increase the convection coefficient (h). This can be accomplished by increasing the fluid flow over the surface since h is a function of the flow velocity and the higher the velocity, the higher the *h*. Example: a cooling fan.

V. ANALYSIS OF HEAT TRANSFER IN SPHERICAL CELL –(THERMAL SYSTEM)

Minimizing the heat transfer for spherical reactor cell then Equation –

$$Min (Q) = h. A. \Delta T$$
$$h = 2 +\{0.5 (\Delta T)^{0.2}\}/ D$$

where
D = Dia of spherical reactor cell.
ΔT = temperature difference.
Q = heat transfer rate.
If we assume that – Heat transfer co-efficient is written in terms of diameter and theta, this is given. And, there is also a strength condition, which says that D theta equal to 20.

$$D . \Delta T = 20 \quad \ldots\ldots(1)$$

Then.- $Q = \{3.14 D^2 .h . \Delta T\}$
Because area of cell ……$A = 3.14 D^2$

$$Q = 3.14 (2D^2 + 0.5 D. \Delta T^{0.2}) \Delta T$$

Now let us say that D is less than 6.3 mm.

1) Maximum number of bits for (D) to be 6. This is only demonstrate the technique by hand calculation.
2) One variable problem for the same reason with one decimal accuracy.

If put the value of Eq. 1 in the Eq. 2 then get .

$$Q = 3.14 \{ 2D^2 + 0.5D (20/D)^{0.2} \}.20/D \quad \ldots\ldots(2)$$
$$Q = 62.83 (2D + 0.91 D^{-0.2}) \quad \ldots\ldots(3)$$

When minimize the heat transfer (Q). then single variable are (Y) maximize …

$$Max. (Y) = 800 -Q \quad \ldots\ldots(4)$$

We can also max. (Y) then get minimize the heat transfer (Q).

since the first term increases with D and the second term decreases with D, there is a hope of optimizing, minimizing or maximizing. Generally, GA has been developed for maximization, because the fitness continuously improves. We can minimize also, but I want to use the maximization. So, I will say, Y is equal to 800 minus Q. I know that, for various combinations of D, Y will not exceed 800, so that Y become, Q will not exceed 800, so that y become negative. So, I will take 800 minus Q as a Y, Or, I can take, maximize 1 by Q, but if you maximize 1 by Q, I will have lot of decimals and all that; you can take. So, Y equal to 800 minus Q or 1200 minus Q, Minimizing Q is maximizing some, a minus Q. Now, we want to max Q; we can also use max Z, max Z equal to 1 by Q, that is also possible.

We can take optimum value …..
Dia of spherical reactor cell.(D) = 0.1388 m
if we take above this optimum value then fail reactor .
put the value of (D) and (ΔT) in the Equation no. 3 then ..

$$Q = 62.83 \{ 2(0.13569) + 0.91(0.13569)^{-0.2}\}$$

Heat transfer (Q_1) = 104 .33 W
Put the value of (D) in Equation no. 1 then …
D . ΔT = 20
Calculate then temperature difference(ΔT_1) = 144.39 K
Then single variable problem…………….Equation no. 4

$$Max. (Y) = 800 - 62.83 (2D + 0.91 D^{-0.2})$$

D is always varies 0 to 6.3 m.

Initially, a population of 2 n to 4 n design vectors are chosen, n equal to 1; n is the number of variables, so I choose 4 n, I took 4 solutions. I am taking 4 solutions. the diameter varies from 0 to 6.3 meter, right. So, I will take 4 solutions arbitrarily, which are in the interval 0 to 6.3. So, I take 0.3, 2, 3 and 5, so that there is no bias; it is uniformly, I do not take close to 6.3 or close to 0, right. So, 0.3, 2, 3 and 5. So if you take 0.3, it is, the binary representation is 00011.

STRINGS NO.	INITIAL POPULATION(RANDOMLY)	(D) VALUE
1.	000111	0.3
2.	010100	2.0
3.	011110	3.0
4.	110010	5.0

IF MAX. (Y) CALCULATE THEN THE VALUE ………..TABLE (1).

STRINGS NO.	INITIAL POPULATION(RANDOMLY)	(D) VALUE	Max. (Y)=f (D)	$P_{select} = f_f / sum f_i$
1.	000011	0.3	689	0.41
2.	010100	2.0	498	0.29
3.	011110	3.0	377	0.22
4.	110010	5.0	130	0.07

SUM = 1695.9 MAX. = 689
AVG. = 423.9 MIN. = 130

A. *Reproduction*

Good strings in a analysis are selected and assigned a large no.of copies to form a mating pool.

INITIAL POPULATION	$P_{select} = f_f / sum f_i$	ACTUAL COUNT	MATING POOL
000011	0.41	2	000011
010100	0.29	1	000011
011110	0.22	1	010100
110010	0.07	0	011110

B. *Mutation*

change 1 to 0 or 0 to 1, but it has to be sparingly done. So, that means, the maximum mutation is 5 percent of the total number of bits. Mutation is to preserve good strings, just in case crossover destroys some good strings.
If crossover are doing then exchange.

Mating pool	Mate randomly selected	Crossover site (randomly)	New result pool	crossover
000011	4	4	000010	001010
000011	3	3	000100	100100
010100	2	3	010011	010011
011110	1	4	011111	011101

AFTER CROSSOVER THEN NEW VALUE RESULT ARE…..

MATING POOL AFTER REPRODUCTION	MATE (RANDOMLY)	CROSSOVER SITE (RANDOM)	NEW RESULT	(D) VALUE	Max. (Y)=f(D)
000011	4	4	000010	0.2	696

000011	3	3	000100	0.4	681
010100	2	3	010011	1.9	511
011110	1	4	011111	3.1	364

SUM = 2253 MAX. = 696
AVG. =563 MIN = 364

The maximum was 689.6, maximum value of Y, the minimum was 130.3. But, using the Darwinian Theory, using the genetic algorithms, while the maximum did not change much, the minimum was substantially improved; therefore, the average was 423.9, the average short up to 563.3, in just one iterations. So, the average will rapidly improve in genetic algorithms.

Residual (R) = $\{Q^2 - (D. \Delta T - 20)^2\}$

Now we Calculate the value then find initial max (Y) are 689 and when crossover and mutation are ocuure then get max. (Y) are 696. So the value of heat transfer (Q) are increase.

If value of dia of spherical cell are (D) =0.1359 m

Then value of heat transfer (Q) = $62.83\ (2D + 0.91\ D^{-0.2})$

$Q_2 = 102.34$ W

If value of dia of spherical cell are (D) =0.1388 m are put in the Equation no. (1). Then

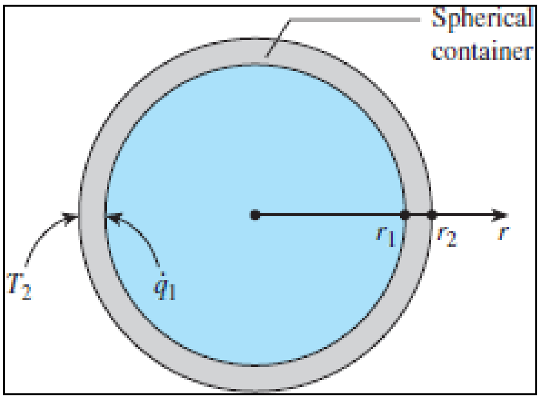
D. $\Delta T = 20$

temperature difference(ΔT_2) = 147 K

VI. Result

Heat transfer from spherical cell (Q_1) = 104 W
Temperature diffirence (ΔT_1) = 144K
Dia of spherical cell (D) = 0.1388 m
After the crossover & mutation and using genetic algorithms with fuzzy logic.
Heat transfer from spherical cell (Q_2) = 102 W
Temperature difference (ΔT_2) = 147K
Dia of spherical cell (D_2) = 0.1359 m

VII. Conclusion



When the heat are flow by the fluid hot & cold .then the heat transfer from spherical reactor cell are initial are Q_1 = 104 W because the dia of spherical cell are 0.1389 m then the temperature difference (ΔT) are144K. So we now used the genetic algorithms with fuzzy logic and crossover and mutation are apply and then finally get the result.

The final result are heat transfer (Q) = 102 W and this result are based on the dia of spherical cell are (D) = 0.1359 m. and then we calculate the temperature difference (ΔT) are 147 K.

So we finally increase heat transfer using genetic algorithms with fuzzy logic.

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