Adaptive Crossover and Mutation in Genetic Algorithms Based on Clustering Technique

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ABSTRACT

Instead of having fixed p_x and p_m, this paper presents the use of fuzzy logic to adaptively tune p_x and p_m for optimization of power electronic circuits throughout the process. By applying the *K*-means algorithm, distribution of the population in the search space is clustered in each training generation. Inferences of p_x and p_m are performed by a fuzzy-based system that fuzzifies the relative sizes of the clusters containing the best and worst chromosomes. The proposed adaptation method is applied to optimize a buck regulator that requires satisfying some static and dynamic requirements. The optimized circuit component values, the regulator's performance, and the convergence rate in the training are favorably compared with the GA's using fixed p_x and p_m

Categories and Subject Descriptors

D.2.2 [**Evolutionary prototyping**]

Keywords

Genetic Algorithms and Real World Applications

1. INTRODUCTION

This paper presents the use of fuzzy logic to adaptively tune p_x and p_m for optimization of PEC throughout the process. By applying the *K*-means algorithm[1] , distribution of the population in the search space is clustered in each training generation. Inference of p_x and p_m is performed by a fuzzy-based system that fuzzifies the relative sizes of the clusters containing the best and worst chromosomes. Both of the population distribution factor and the computational efficiency, as compared with[2] and[3], are considered. The proposed adaptation method is applied to optimize a buck regulator that requires satisfying some static and dynamic requirements. The decoupled optimization technique as proposed in[4] is used. Nevertheless, without loss of generality, the proposed parameter adaptation scheme can be applied to other GA-based optimization problems. The optimized circuit component values, the regulator's performance, and the convergence rate in the training are favorably compared with the GA's using fixed p_x and p_m.

2. ADAPTIVE CONTROL OF p_x AND p_m

Biological evolution shows that p_x and p_m should be adapted and should depend on the evolution state[5]. Thus, in order to enhance the training efficiency of[4], an adaptive approach for tuning p_x and p_m is proposed. The basic concept is based on considering that p_x determines the probability of reproduction from parent chromosomes and p_m determines the probability of creation from a parent chromosome in different training states. Fig. 1 illustrates the strategy of tuning p_x and p_m in four optimization states, including initial state, under-matured state, maturing state, and matured state [5]. In order to prevent premature convergence of the GA to a local optimum, it is essential to be able to identify whether the GA is converging to an optimum. The proposed method suggests the use of the relative population distribution to define the training state. The first step is to partition the population into clusters. Chromosomes of having similar component vectors are grouped in the same cluster. The second step is to use a fuzzy system that fuzzifies the relative sizes of the clusters containing the best and worst chromosomes to determine p_x and p_m. The procedures are described as follows.

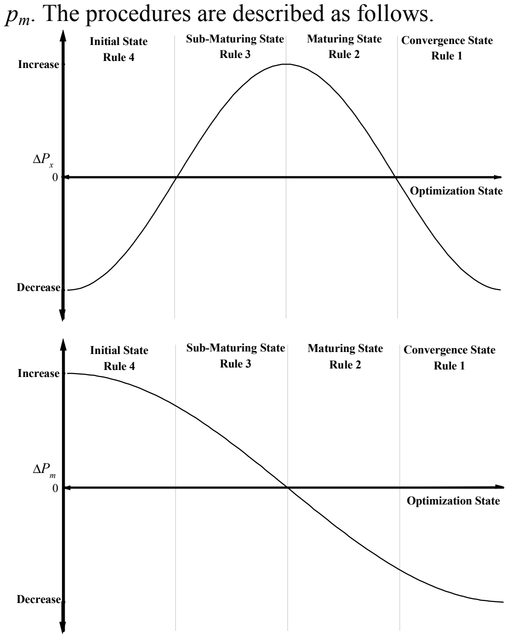

Fig 1. Illustrations on adjusting p_x and p_m in different optimization phases.

A. Clustering of the Population

Although *K*-means algorithm can only partition sub-optimal clusters, it is sufficient for this particular application to depict the chromosome distribution.

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B.Tuning Rules for p_x and p_m

Tuning of p_x and p_m in the proposed fuzzy inference system is based on considering the relative cluster sizes of G_B and G_W (i.e., $\hat{G}_B$ and $\hat{G}_W$). The following four rules for tuning p_x and p_m are defined and are tabulated in Table I.

Table I Strategy in tuning p_x and p_m

Size of the cluster containing the WORST chromosome			
	Large	P_x Decrease P_m Increase	P_x Increase P_m Decrease
	Small	P_x Increase P_m Increase	P_x Decrease P_m Decrease
		Small	Large
		Size of cluster containing the BEST chromosome	

Rule1-The best chromosome is in the largest cluster whilst the worst chromosome is in the smallest cluster.
Rule2-G_B equals G_W. Both of them are the largest among others.
Rule3-G_B equals G_W. Both of them are the smallest among others.
Rule4-The best chromosome is in the smallest cluster whilst the worst chromosome is in the largest cluster.

C.Fuzzy-based tuning mechanism for p_x and p_m

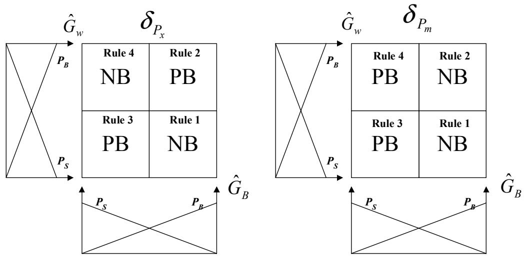

Fig 2. Illustrations on adjusting p_x and p_m in different optimization phases

Table II Fuzzy control rules for tuning p_x and p_m

Rule for δ_{P_x}
Rule 1=(Rule (0,1)): If ($\hat{G}_B$ is P_B) and ($\hat{G}_W$ is P_S) then δP_x=NB
Rule 2=(Rule (1,1)): If ($\hat{G}_B$ is P_B) and ($\hat{G}_W$ is P_B) then δP_x=PB
Rule 3=(Rule (0,0)): If ($\hat{G}_B$ is P_S) and ($\hat{G}_W$ is P_S) then δP_x=PB
Rule 4=(Rule (1,0)): If ($\hat{G}_B$ is P_S) and ($\hat{G}_W$ is P_B) then δP_x=NB
Rule for δ_{P_m}
Rule 1=(Rule (0,1)): If ($\hat{G}_B$ is P_B) and ($\hat{G}_W$ is P_S) then δP_m=NB
Rule 2=(Rule (1,1)): If ($\hat{G}_B$ is P_B) and ($\hat{G}_W$ is P_B) then δP_m=NB
Rule 3=(Rule (0,0)): If ($\hat{G}_B$ is P_S) and ($\hat{G}_W$ is P_S) then δP_m =PB
Rule 4=(Rule (1,0)): If ($\hat{G}_B$ is P_S) and ($\hat{G}_W$ is P_B) then δP_m=PB

3. DESIGN EXAMPLE & COMPARISONS

The proposed method is illustrated with the same example in [4]. The circuit schematic is shown in Fig. 3. The PCS is a classical buck converter and the FN is a proportional-plus-integral controller. In[4], p_x (= 0.85) and p_m (= 0.25) are fixed in the GA's. Fig. 4 shows the comparisons of the fitness values against the training generations with the fixed and proposed fuzzy-controlled p_x and p_m. It can be seen that the fuzzy-controlled scheme can significantly improve the fitness values.

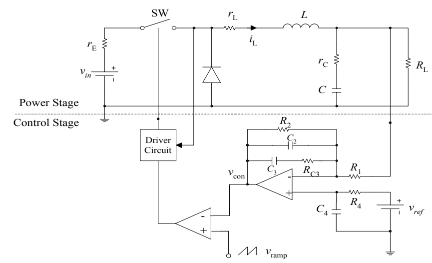

Fig. 3. Schematics of the buck regulator in[4]

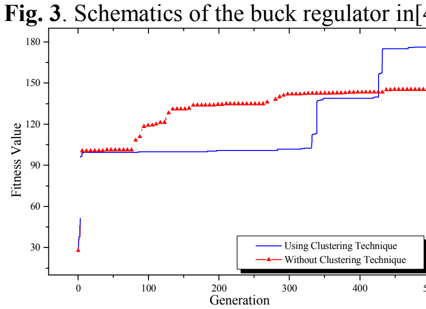

Fig.4 Comparisons of the fitness values against the training generation using fixed and fuzzy-controlled p_x and p_m

4. CONCLUSIONS

A fuzzy-controlled crossover and mutation probabilities in GA's for optimization of PECs has been proposed. They are determined adaptively for each solution of the population. It is in the manner that the probabilities are adapted to the population distribution of the solutions. This not only improves the convergence rate of the GA, but also prevents the GA from getting stuck at a local minimum. A buck regulator has been optimized. The results are favorably compared with the ones using GA's with fixed probabilities.

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