fuzzy logic controller was used to find the values for *F* and C_r for the candidate *i* (F_i and C_{ri}). The FLC-MODE (Fuzzy Logic Controlled Multi-objective Differential Evolution) [52] was introduced by FengXue et al in the year 2005, as similar to *FADE*.

An Iterative Function System Based Adaptive *DE* was proposed by Ya-Liang Li, et. al. [53]. In this algorithm the control parameters are adapted using an iterative function system. The $F_{i,G}$ and $CR_{i,G}$ values are adapted using the following equations

$$F_{i,G+1} = \begin{cases} \alpha_1 F_{i,G} + (1-\alpha_1) r_1, & iff(u_{i,G}) < f(x_{i,G}) \\ \alpha_2 F_{i,G} + (1-\alpha_2) r_2 & otherwise \end{cases} \quad (60)$$

$$CR_{i,G+1} = \begin{cases} \alpha_3 CR_{i,G} + (1-\alpha_3) r_1, & iff(u_{i,G}) < f(x_{i,G}) \\ \alpha_4 F_{i,G} + (1-\alpha_4) r_2 & otherwise \end{cases} \quad (61)$$

Here, $\alpha_1, \alpha_2, \alpha_3$ and α_4 are uniformly generated within the range $(0,1)$. The parameter r_1 is set to 0.5 and r_2 is set to 1.

Patricia Ochoa et.al proposed *FDE* (Fuzzy Differential Evolution), which uses concept of fuzzy system for parameter adaptation [54]. The fuzzy system added to *DE* will give the best possible values for the control parameters. The fuzzy system has 3 membership functions (FN_1, FN_2 and FN_3) to mean the low, medium and high values of the parameters. It also used 3 fuzzy rules to update the values of the control parameters.

In 2009, M.G. Epitropakis et al. introduced an evolutionary approach towards self-adapting *DE*, known as *ESADE* [55]. In *ESADE*, a unique strategy was followed in finding the values of the control parameters. It uses two *DE* algorithms, one is to find the mutation rate (*F*), and the other for optimizing the given objective function. In the first *DE* algorithm to find *F* value, a one-dimensional population is initialized as follows,

$$Xg = \{Fg\} \quad (62)$$

where *Fg* corresponds to possible values of *F*. Rather than initializing it with values in the range (0.1, 1.0], based on their study they have initialized the population with values from a normal distribution with mean 0.5 and standard deviation 0.3. Once, the population has been initialized in the first *DE*, one generation of the second algorithm is performed. Here the fitness value of the best candidate ($f(x_{gbest})$) is taken and it is considered as the fitness value of corresponding individual of the first algorithm. For adapting C_r, a normal distribution with mean 0.6 and standard deviation 0.1 is considered, and values are taken from this normal distribution at every generation. Thus, in *EPSADE*, the first algorithm gives the Scaling factor value and using this value the second *DE* algorithm optimizes the given objective function.

Pravakar Roy et.al proposed Differential Evolution that is Genetically Programmed [56] which ensures a self-adaptive mechanism in the *DE* algorithm. Here, the initial preparations are made in such a way that the need of *F* is null. The system finds out the best crossover rate as follows, for each individual in the population of *GP*, a C_r value is also associated with it and it is updated during the natural evolution process of *GP*. Initially it is taken from a Gaussian distribution and later the *GP* will alter the values based on the predetermined fitness value. Also a counter is kept for the number of times the alteration has performed.

The adaptation strategies discussed in this section have used additional components to tune the values for the control parameters.

V. F and Cr Adaptation Strategies - Insight

The research works focusing on control parameter adaptation of *DE* algorithm are grouped in to four categories and presented in Table 1. Due to large number of reports available in the literature, this paper aimed to consider the research works for adapting the parameters *F* and C_r.

TABLE I
LIST OF PAPERS UNDER EACH CATEGORY

Categories			
I Classical Approaches	**II Encoding of Parameters**	**III Deriving from History/Pool**	**IV With Added Logic**
[5],[6],[7], [8],[9],[10], [11],[12],[13], [14],[15],[16], [17],[18],[19],[20],[21],[22],[23],[24],[25], [26].	[27],[28],[29], [30],[31],[32], [33],[34],[35], [36],[37],[38],[39],[40],[41],[42], [43],[44].	[45],[46],[47] [48],[49],[50]	[51],[52], [53],[54], [55],[56]

The research works in Category I use author defined equations to calculate the values for the parameters. Many authors also have considered using statistical distribution to select the values for the control parameters. In category II, the algorithms which encode the control parameters along with other parameters of the candidates are considered. Evolution of those parameters is done by normal *DE* process or by some other newly added algorithm. Recording the history of behaviour of *DE* in previous generations and deriving necessary information from them to decide the control parameter values for the forthcoming generations is another strategy for parameter adaptation. Research works using this strategy are grouped under this category III. Finally, in Category IV the works which consider to add additional component to *DE* for parameter adaptation are grouped.

VI. Conclusions

The critical parameters of *DE* algorithm are *F*, C_r and *NP*. Selecting suitable values for them are very important as well as crucial for successful application of *DE* for any optimization problem. There exists no standard method for choosing values for these parameters. However, to alleviate this many parameter adaptation strategies are proposed in the literature. The existing adaptation strategies are identified and are categorized in to four groups, and brief insight about each of the identified strategies are presented in this paper. The categories of adaptation strategies presented in this paper are strategies with classical approaches, strategies with encoding of parameters, strategies using history/pool and strategies adding new components.

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