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A multi-population electromagnetic algorithm for dynamic optimisation problems

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ABSTRACT

This paper is derived from an interest in the development of approaches to tackle dynamic optimisation problems. This is a very challenging research area due to the fact that any approaches utilised should be able to track the changes and simultaneously seek for global optima as the search progresses. In this research work, a multi-population electromagnetic algorithm for dynamic optimisation problems is proposed. An electromagnetic algorithm is a population based meta-heuristic method which imitates the attraction and repulsion of the sample points. In order to track the dynamic changes and to effectively explore the search space, the entire population is divided into several sub-populations (referred as multi-population that acts as diversity mechanisms) where each sub-population takes charge in exploring or exploiting the search space. In addition, further investigation are also conducted on the combination of the electromagnetic algorithm with different diversity mechanisms (i.e. random immigrants, memory mechanism and memory based immigrant schemes) with the aim of identifying the most appropriate diversity mechanism for maintaining the diversity of the population in solving dynamic optimisation problems. The proposed approach has been applied and evaluated against the latest methodologies in reviewed literature of research works with respect to the benchmark problems. This study demonstrates that the electromagnetic algorithm with a multi-population diversity mechanism performs better compared to other population diversity mechanisms investigated in our research and produces some of the best known results when tested on Moving Peak Benchmark (MPB) problems.

1. Introduction

Most of the real world optimisation problems are dynamic in nature i.e., the problem parameters are either revealed or changed during the search progress. Their vital application makes them an on-going challenging problem for the research community. Unfortunately, optimisation methods that have been used to solve static problems face difficulties to directly apply on dynamic one. This is because the problem keeps changing and therefore an efficient method is needed to track the changes and seek for the global optima solution simultaneously. Despite the fact that population based methods have proven to be efficient in solving static problems, they are usually suffer from the diversification when dealing with the dynamic problems [1]. The main reason for this is that the *traditional* population based methods usually converge to a single optima [2,3], whilst in dynamic problems the solution landscape keeps changing which means that there are several local optima points that would be revealed during the solving process. One of the ways to overcome the shortcomings of population based methods is to maintain the population diversity.

In consequence, several population diversity mechanisms have been employed within population based methods in order to tackle the dynamic optimisation problems. An example of these approaches is the use of memory mechanism within genetic algorithm to store some promising solutions and then use these solutions to diversify the search by replacing the new solution with the old one (if the quality of the new one is better than the old solution) once the changes are detected [4]. Another way to maintain the population diversity is to use a multi-population within the evolutionary algorithms. The entire population is divided into sub-populations where each sub-population is in charge of either exploring or exploiting the search space [5]. Other examples of population based methods that have been employed for dynamic

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optimisation problems are Genetic Algorithm (GA) [6], Particle Swarm Optimisation Algorithm (PSO) [7,8] and Differential Evolution (DE) [9].

Obviously, the success of the population based methods is largely due to the use of the population diversification mechanism and therefore it is more important to work on the development of the population based methods for the dynamic optimisation problems with the focus on how to maintain the population diversity. However, as there is no best mechanism so far to maintain the population diversity, thus create a plenty of room for further research work. Following to this line of thought, in this work we propose a multi-population electromagnetic (MP-EM) algorithm for dynamic optimisation problems. Electromagnetic algorithm (EM) is a population based meta-heuristic method which imitates the attraction and repulsion of the sample points and moves them towards a high quality solution while avoiding the local optima [10]. EM has been successfully applied to many optimisation problems such as examination timetabling problems [11], vehicle routing problems [12], and project scheduling [13]. However, to our knowledge, there is no work has been undertaken to solve dynamic optimisation problems. The attractive feature of EM is its ability to explore and exploit the search space simultaneously. Exploration in EM is achieved via the use the population of solution, while, exploitation is achieved by using a local search algorithm. In order to use EM for dynamic optimisation problems and to track the changes that usually occur during the solving process, the population of solutions in EM is further divided into sub-populations. These sub-populations are categorised into two types i.e., (i) exploration and (ii) exploitation. By doing so, each sub-population will simultaneously search different areas in the search space. Thus, if one of these areas becomes the new global optima, information gained by the sub-population can be used to effectively explore the search space by merging the sub-populations into a single population and then re-dividing them accordingly.

The proposed algorithm is tested on the well-known Moving Peaks Benchmark (MPB) problem that has been widely used by other researchers [4]. To verify the effectiveness of dividing the entire population into sub-populations, we compare its performance over the hybridisation of the electromagnetic algorithm with three well known population diversity mechanisms i.e., random immigrant, memory mechanism and memory based immigrant scheme. Experimental results show that the proposed multi-population achieved good results when compared with other hybrid electromagnetic algorithms (implemented herein), indicating that the multi-population is efficient in tracking the changes in the problems. Further comparison with other approaches in the literature shows that the proposed multi-population is capable of obtaining good results on a different number of peaks and outperforms others on some instances.

The remainder of the paper is organised as follows: Section 2 briefly presents the related work concerning MPB problem. Section 3 presents the proposed algorithm. Experimental results are discussed in Section 4. Finally, some brief concluding comments are provided in Section 5.

2. Related work

In the past decade, the number of published papers that deals with dynamic optimisation problem has increased. This implies that dynamic optimisation problems have crucial impact on the real world applications. Among these problems, the Moving Peak Benchmark (MPB) has attracted much attention and numerous approaches have been developed to solve this problem. MPB was first introduced by Branke [4] and since that time, many researchers have used MPB as a benchmark to assess the performance or capability of their algorithms [4]. MPB involves several parameters such as height, width and location. The dynamic aspect of MPB occurs when the value of the height, width and location parameters are changed. These changes cause further changes in the solution landscape which then accordingly leads to the changes in the location of the global optima.

In this section, related approaches that have been applied on MPB are presented since this work is focussed on MPB. The population-based approaches have shown good performances when dealing with the dynamic optimisation problems in reviewed literature [5]. These approaches are usually modified or hybridised in order to not only find the global optima but to keep tracking the changes of the problem by maintaining the population diversity. According to [4,14], approaches that have been proposed to solve dynamic optimisation problems are categorised into four types.

i. Approach that increases the population diversity by changing the parameter values. This approach works as follows: once the change in the environment is detected, the parameter values that control the diversification behaviour are increased. For example, the use of an adaptive mutation operator where the mutation rate will increase or the hyper-mutation techniques are used [15]. Less research are focussed on this category since it has not been proven reliable in comparison with other approaches. This may be due to a tuning process where a number of parameters need to be tuned in advance.
ii. Approach that maintains the population diversity by replacing some individual or solution in the current population. This approach works as follows: after a fixed number of iterations, a subset of solution is randomly created and replaced with the solution in the current population. An example of this approach is the immigrant approach [16]. This approach was first used within Particle Swarm Optimisation (PSO) for MPB [7], where each particle is attached to a virtual charge. In order to increase the population diversity, particles follow the electrostatics laws in such a way that during the search process, particles repel from each other to explore a wider area of the search space. Later, Blackwell and Branke [17] used the quantum theory within the PSO to maintain the population diversity. Pelta et al. [18,19] developed a multi-agent decentralised strategy for dynamic optimisation problems where the agents cooperate with each other by changing the promising solutions in order to diversify the search process. Despite achieving the promising results, the main drawback of this approach however is that it may not work well if the dynamic change is cyclic because the solutions used to replace the current population are randomly generated. In addition, the number of individuals to be replaced is a problem dependent.
iii. Approach that embeds a memory mechanism to store some promising solutions to use them in the future. This approach works as follows: first a set of promising solution is kept. Then, if the change occurs, the solutions re-inject themselves into the current population. An example of this approach is in the use of the explicit memory mechanism. Branke [4,20] implemented an explicit memory to store good solutions that will be used during the optimisation process. This memory is updated as the search progresses by replacing the old solution with the new one if the quality of the new one is better than the old one. This approach is very effective in dealing with cyclic changes due to the re-insertion of the stored solution into the current population and will therefore overcome the limitation that the immigrant approach has. However, this approach has a few parameters that need to be set in advance.
iv. Approach that keeps track of the changes by dividing the whole population into sub-populations. This approach works as follows: the population is divided into multi-populations and