Lecture Notes in Networks and Systems

Volume 67

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Vincenzo Piuri · Valentina Emilia Balas · Samarjeet Borah · Sharifah Sakinah Syed Ahmad
Editors

Intelligent and Interactive Computing

Proceedings of IIC 2018

Springer
Preface

Intelligent and interactive computing is assorted of research outcomes of the 2nd International Conference on Intelligent and Interactive Computing 2018 (IIC 2018). IIC 2018 is jointly organized by the Department of Intelligent Computing and Analytics (ICA) and the Department of Interactive Media (MI), Faculty of Information and Communication Technology (FTMK), Universiti Teknikal Malaysia Melaka (UTeM). It is an academic conference with the theme “Intelligent and Immersive Computing towards Industrial Revolution 4.0”. The aim of this conference was to bring together academicians, researchers, developers and practitioners working in this domain of research from academia and industry to share their experiences and to exchange their ideas. IIC 2018 also serves as a platform for the dissemination of state-of-the-art developments in intelligent and interactive computing technology, robotics, automation and its applications.

This volume of proceedings provides a prospect for readers to encompass with a collection of stated papers that were presented during IIC 2018. Divided into four parts, the 46 papers published here address the theme, “Intelligent and Immersive Computing towards Industrial Revolution 4.0”. Part I deals with the theory of and applications for computational intelligence using fuzzy system, rough set, neural networks and deep leaning. Part II continues with applications of various soft-computing techniques, such as Bat algorithm, cuckoo search and artificial bee colony algorithm. Part III deals with system and security theories and applications. Part IV focuses on both multimedia and immersive technologies.

Finally, it is hoped that this book will be able to disseminate required knowledge to the researchers, policymakers, students and academicians in the fields of computational intelligence, machine learning, multimedia technologies and immersive technologies. The book will be a valuable resource to graduate students and anyone interested to conduct research in the said domains.
The volume editors want to convey sincere thanks to all the contributors, reviewers and the editorial board members for making this effort a successful one. The editors also appreciate the help and understanding of the editorial staff at Springer, who supported the publication of this volume in the Lecture Notes in Networks and Systems (LNNS) series.

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Sikkim, India
Durian Tunggal, Malaysia

Vincenzo Piuri
Valentina Emilia Balas
Samarjeet Borah
Sharifah Sakinah Syed Ahmad
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Part I

Theory of and Applications for Computational Intelligence
Dynamic Solution Probability Acceptance Within the Flower Pollination Algorithm for Combinatorial $t$-Way Test Suite Generation

Abdullah B. Nasser, Kamal Z. Zamli and Bestoun S. Ahmed

Abstract In this paper, the enhanced Flower Pollination Algorithm (FPA) algorithm, called imFPA, has been proposed. Within imFPA, the static selection probability is replaced by the dynamic solution selection probability in order to enhance the intensification and diversification of the overall search process. Experimental adoptions on combinatorial $t$-way test suite generation problem (where $t$ indicates the interaction strength) show that imFPA produces very competitive results as compared to existing strategies.

Keywords Search-based software engineering · Meta-heuristic · Flower pollination algorithm · $t$-way testing · Test suite generation

1 Introduction

Meta-heuristic is higher level of stochastic methods that attempt to escape from local optimum, by applying intelligent concepts of exploring and exploiting search space. Over the years, meta-heuristic algorithms have proven successful for solving hard optimization problems in many areas of computer science and software engineering. Many of its applications include software design, project planning and cost estimation, requirement engineering, network packet routing, protein structure prediction, software measurement, and software testing [1–6]. In recent years, active research on meta-heuristic algorithms have resulted in much advancement in the literature. Some
of the developed meta-heuristic algorithms include Gray Wolf algorithm (GW), Bat Algorithm (BA), Fruitfly Algorithm (FA), Whale Algorithm (WA), Jaya Algorithm (JA), Differential Evolution (DE), Great Deluge Algorithm (GDA), Symbiotic Optimization Search (SOS), Particle Swarm Optimization (PSO), Sine Cosine Algorithm (SCA) as well as Firefly Algorithm (FA), to name a few [7].

Most of abovementioned algorithms use parameters to guide and control the local and global parts of search process (via intensification and diversification). Here, intensification explores the promising neighboring regions and diversification to ensure that regions of interests in the search space have been sufficiently explored. For example, GA uses crossover, mutation, and selection operators, and TLBO uses teacher and the learner’s operator.

Complementing existing work, our work focuses on enhancing the exploration (i.e., ensuring diversity of solution) and exploitation (i.e., manipulating the current best to get better solution) of the Flower Pollination Algorithm (FPA). We argue that existing work on FPA [8, 9] uses a simple probability $p_d$ to control the exploration (i.e., global pollination) and exploitation (i.e., local pollination). As the search space is dynamic (i.e., based on the given configuration), any fixed and preset $p_d$ can be counter-productive as far as exploration and exploitation are concerned. In fact, there should be more exploration (i.e., via global pollination operator) in the early part of the searching process. Then, towards the end, there should be more exploitation (i.e., via local pollination operator). To do so, FPA needs to do away with its $p_d$ (i.e., probability selection of operators) allowing both global and local pollination to run in sequence. Here, the probability is introduced as a dynamic parameter to select the solution itself (rather than the operators). Initially, the probability is high to accept all solution (for diversification). This probability will decrease with time and only allows good solution to be accepted thereafter.

In this paper, the enhanced Flower Pollination Algorithm (FPA) algorithm, called imFPA, has been proposed. As a case study, we adopt the problem from Search-Based Software Engineering domain involving the $t$-way combinatorial test suite generation problem [6, 10, 11] (where $t$ represents the interaction strength). Experimental results show that imFPA produces very competitive results as compared to existing strategies.

2 Overview on Combinatorial Testing

Combinatorial testing (or $t$-way testing) is a sampling technique to minimize the interaction test suite size in a systematic manner. Within $t$-way testing (where $t$ indicates the interaction strength), all $t$-combinations of system’s components must be covered at least once. As illustration, Fig. 1 shows the window of power and sleep setting in Windows 10. The window consists 4 components (i.e., time to turn off screen on battery power, time to turn off screen when plugged in, time to sleep on battery power and time to sleep when plugged in), each component or input has 16
values (i.e., represented as 1, 2, 3, 5, 10, 15, 20, 25, 30, and 42 min as well as 1, 2, 3, 4, 5 h, and one value termed never).

Ideally, there is a need to test all possible interactions between the inputs’ values with 65,536 test cases. However, if only every two pairs (2-way testing) of the components are considered, the final test suite size can be reduced to 310 test cases. Here, the final test suite should include all possibilities of any two inputs at least once, which can detect 76% of software failure [12], while 3-way testing can minimize the test cases to 5300.

3 Related Works

Recently, there are active research on adopting meta-heuristic algorithms for addressing the $t$-way test suite generation problem. In general, meta-heuristic-based strategies exploit a random set of solutions, called population. The population is perturbed using a sequence of mathematical transformation (i.e., population update) in order to find better solution. At each particular iteration, the best candidate is adopted in the final test suite.

GA and ACA [13] are the first population-based algorithm has been used for generating $t$-way testing. GA adopted three operators, selection, crossover, and mutation,
for diversification and intensification. ACA are probability algorithm controlled by 6 parameters (i.e., pheromone control, pheromone persistence, maximum stale period, pheromone amount, elite ants, and heuristic controls) apart from population size and number of iteration [13].

Due to its performance, PSO has been adopted for \( t \)-way interaction test suite generation in [14, 15]. The mathematical transformation adopted by PSO controls exploration and exploitation based on three parameters (termed social and cognitive parameter, and inertia weight) and is implicitly implemented by updating its particle velocity [16]. Unlike PSO, HS adopts probabilistic-gradient mathematical transformation to move to better solution. In addition, HS also employs elitism selection to ensure sufficient diversification of solution [17].

Both CS [18] and FPA [19] use Lévy flight in search process as the main technique to update the current population. Lévy flight can be considered as both diversification and intensification depending on generated step size. Addition to Lévy flight, CS uses elitism mechanism to increase the diversity of the population, while FPA uses learning mechanism to intensive the search around each flower (i.e., Local pollination). Apart from CD and FPA, Bat Algorithm (BA) has also been used for generating \( t \)-way test suite. The algorithm mimics the hunting behavior of Microbats. The intensification part in is implemented using random walk around the current best, while diversification part shares some similarity to PSO [20].

Unlike many earlier works, High-Level Hyper-Heuristic (HHH) [21] adopts more than one algorithm for generating \( t \)-way test suite. In the current implementation, HHH uses five meta-heuristic algorithms; TS as high-level selection algorithm, as well as PSO, CS and GNA as low-level algorithms. Adaptive TLBO (ALTBO) [22] has also been used for generating test suite. ATLBO improves the selection of local and global search operations through the adoption of fuzzy inference rules. Apart from ATLBO, Q-learning with Sine Cosine Algorithm (QSCA) [23] has also recently been adopted to address the \( t \)-way generation problem.

4 Proposed Strategy

The standard FPA starts by generating a number of random population, then applies global pollination or local pollination based on the switch probability \( p_a \in [0, 1] \) [24]. The complete pseudo code of the standard FPA is presented in Fig. 2.

Unlike FPA, imFPA adopts a new mechanism for selecting local and global pollination. Like FPA, the new generated solution (i.e., either from global pollination or local pollination) will be accepted if it is better than the current solution. If not, the updated solution will only be accepted with probability \( P(f(x), f(x_{\text{new}}), \text{success}_\text{rate}) \) as shown in Fig. 3. In other words, the selection mechanism considers the total success rate of global and local pollinations in order to decide whether to accept or reject the poor current solution. By doing so, imFPA allows a systematic way to get out of local optima.
1. Objective function \( f(x), x = (x_1, ..., x_d) \);
2. Initial a population of \( n \) flows \( x_i \) (\( i = 1, 2, ..., n \));
3. while \( t < \text{MaxGeneration} \) or (stop criterion)
   for \( i = 1 : n \) (all \( n \) flowers in the population) Do
   if ( rand < \( p \) )
     Draw a (d-dimensional) step vector \( L \) which
     obeys a L'\( \text{\'} \text{\'} \)evy distribution
     Global pollination via \( x_i^{t+1} = x_i^t + y\text{L}^\nu(y)(x_i^t - \text{gbest}) \)
   else
     Randomly choose \( j \) and \( k \) among all the solutions
     local pollination \( x_i^{t+1} = x_i^t + \epsilon(x_j^t - x_i^t) \)
   End if
   Evaluate new solutions
   If new solutions are better, update them
   Find the current best solution \( \text{gbest} \)
   end while
   Postprocess results;
End-Procedure

Fig. 2  Pseudocode of FPA algorithm

Fig. 3  Pseudocode of imFPA for \( t \)-way test suite generation
5 Results and Evaluation

In this section, imFPA is compared with state-of-the-art \( t \)-way strategies including SA, GA, ACA, PSO, HSS, HHH, CS, and FPA. Different system configurations are used as shown in Table 1. The first and second columns, where \( x^y \) indicates that the system configuration that has \( y \) parameters with \( x \) values, and \( t \) is the required interaction. Each cell in Table 1 displays the best test case obtained by each strategy, while the darkened cell displays the best minimum size obtained. The NA entries indicate that no published results are available for the case of interest. For experimental setup, the values of population size = 500, and iteration = 500 have been used. Each configuration is run 30 times, and the best result obtained is recorded.

Table 1 depicts that the results of imFPA are very competitive with the existing strategies. Specifically, imFPA obtains the most minimum results for five cases (S1, S3, S8, S11, and S14), while HHH obtains the best result for six cases. In general, we can observe that meta-heuristic based strategies, such as HS, CS, HHH, FPA, and imFPA, perform better than other strategies.

In order to assess the contribution of imFPA and investigate the behavior of FPA and imFPA, global and local pollination for both FPA and imFPA have been tracked. As Fig. 4 shows, the mean percentage of global and local imFPA dynamically change based on the problem, however, in FPA, it remains the same for all problem instances. Comparatively, the dynamic selection within imFPA can be compared with the selection of candidate solution in SA. In SA, the selection probability (of poor solution) always decreases with time. Unlike SA, the selection probability in imFPA increases

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<th>GA</th>
<th>ACA</th>
<th>PSO</th>
<th>HSS</th>
<th>HHH</th>
<th>CS</th>
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<td>3^4</td>
<td>2</td>
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or decreases based on the need of the search process. In this manner, imFPA provides an adaptive way to decide on whether or not to select or discard poor solution.

6 Concluding Remarks

In this paper, an improved algorithm based on Flower Pollination Algorithm (FPA), called imFPA, is proposed. imFPA provides a new mechanism for candidate solution’s selection. The experimental results show that imFPA produces competitive results comparing with state-of-the-art strategies. As part of the future work, we are currently investigating imFPA for constraints software product lines test suite generation.

Acknowledgements This work is funded by “FRGS Grant from the Ministry of Higher Education Malaysia titled: A Reinforcement Learning Sine Cosine based Strategy for Combinatorial Test Suite Generation (grant no: RDU170103)”.
References


Aggregating Multiple Decision Makers’ Judgement

Jeremy Y. L. Yap, Chiung Ching Ho and Choo-Yee Ting

Abstract Selecting the best location to establish a new business site is very important in order to achieve success. It is therefore one of the most important aspect in any business plan. Multi-criteria decision-making methods such as the Analytic Hierarchy Process (AHP) has been used to elicit information that supports the decision of business site selection. However, AHP often involves multiple decision makers, each with their own opinions and biases. Different decision makers will have different opinions and views on the importance of the criteria and sub-criteria in the AHP model. In this study, three aggregation methods that can be used to carefully aggregate the resultant judgements from the multiple decision makers to form a single group judgement are discussed. The goal of obtaining the single group judgement is to use it as input to the AHP model in order to achieve the goal of selecting the most suitable business location. The study case for this paper is that of the selection of a location for a telecommunication payment point. From this study case, a conclusion can be drawn for the best aggregation method for the selection of the best location to set up a business of the telecommunication nature.

Keywords AHP · Decision support · Location · Site selection · Data analytics · Decision analysis

1 Introduction

Selecting the correct location for a business site is one of the most important strategic decision that decision makers have to face [1]. This decision plays a role in determining the success of the business in monetary terms [2] as well as the image of the
Therefore, the selection needs to undergo thorough judgements that may involve several criteria and a number of decision makers.

When facing complex decision problems, multi-criteria decision methods such as the Analytic Hierarchy Process (AHP) method is often used to aid decision makers in finding a solution to the problem. The resultant ranking from the AHP model is used to aid decision makers in selecting the best site to establish a business. However, AHP often involves multiple decision makers, each with their own opinions and biases. Different decision makers will have different opinions and views on the importance of the criteria and sub-criteria in the AHP model. It is therefore important to carefully aggregate the resultant judgements in order to form a single group judgement that can be used as input to the AHP model in order to achieve the goal of selecting the most suitable business site.

Many studies have been done to propose methods to aggregate the judgements to form a single group judgement. With the availability of these aggregation methods, the selection of the best method to be used in deciding the best site to set up a business will be required. Comparisons of the various aggregation method have been studied in the past [4, 5], however there have not been any studies on the application of these methods on the selection of a telecommunication payment point. A telecommunication payment point in this study is the business site in which customers will go to in order to make payments for their telecommunication services and any other matters that relate to the telecommunication company.

This study looks into the judgements of four different decision makers on which of the four alternative is the best site for the telecommunication payment points, and the judgements are then aggregated to find the ranking of the alternatives. These four alternatives were chosen as they were the top four performing alternative in the scope of Klang Valley. Only four alternatives were chosen to limit the amount of pairwise comparisons to be performed. This ranking is then compared to the real-world rankings of these sites based on their sales performance to validate if the AHP model and the aggregation method.

In Sect. 2, the AHP model that is used to select the best telecommunication payment point is discussed. It is then followed by a discussion on the aggregation methods that were used in this study in Sect. 3. In Sect. 4, the resultant ranking of applying three of the aggregation methods in this study is shown. In Sect. 5, two rank correlation coefficients were used and discussed to determine the degree of similarity of the resultant ranking of the AHP model and the real-world ranking. Finally, in the Sect. 6, a recap of the whole study and discussion on future steps to be undertaken following this study is shown.

2 AHP Model for Telecommunication Payment Point

This study focuses on the selection of the best location for a telecommunication payment point in Selangor, a state in Malaysia. The scope of the case study is in the area of Klang Valley. The case study involved a questionnaire given out to decision
Aggregating Multiple Decision Makers’ Judgement

Fig. 1 AHP model for telecommunication payment point

makers of the telecommunication payment point to perform pairwise comparisons between the criteria, sub-criteria, and location. There were four (4) decision makers involved in partaking of filling the questionnaire. The breakdown of the AHP model is: three (3) criteria, six (6) sub-criteria; and four (4) locations. Figure 1 shows the AHP model for telecommunication payment point based on the model proposed by Yap et al. [6].

2.1 Criteria 1: Establishment

To find the most suitable location in order to set up the business site, decision makers have to ensure that the location is appropriate and is able to accommodate and serve its customers. In this case study of selecting the location for a telecommunications payment point, the establishment that is chosen needs to be able to cater for the number of customers that visit the payment point. The sub-criteria that were found to be contributing to the criteria of Establishment are: (i) Parking Spaces, (ii) Number of Counters, and (iii) Access to Entrance.

The number of parking spaces plays a significant role in determining if an establishment is suitable as many customers would go to the site using their own means of transport. The number of parking spaces need to be adequate.
A long waiting time should be avoided in order to satisfy the needs of the customers. Hence, the number of counters that can be set up in the establishment needs to cater to the expected number of customers. More counters would enable a higher number of customers to be serviced hence reducing the waiting time.

Access to entrance refers to how easily a customer would be able to enter or exit the establishment [7]. The access to entrance of the establishment is determined by the presence of automatic sliding doors, ramps, or stairs [6].

2.2 Criteria 2: Location

When determining the location to set up a new business site, there are several aspects of the location that have to be taken into account. The aspects include (i) Visibility, (ii) Traffic Density, and (iii) Accessibility.

Visibility is defined as the ability of customers to view the business site [6]. A site that is easily seen from the walkway or main road will enable the customers to see it. A structure that can be used as a landmark will serve to ease visibility [6].

The traffic density of the location serves to indicate the number of cars passing the business site. When the area is heavily dense, it shows the potential of the site having more customers.

Decision makers must take into account customers that travel using public transportation. Therefore, the selection of site must take into consideration the accessibility of the site by public transportation [6].

2.3 Criteria 3: Population Density

The population density of an area needs to be considered when selecting the location to set up a business site. An area with a higher population density will garner more revenue for the business as the larger number of customers will be in the area.

3 Three Aggregation Methods

Aggregation can be performed at the individual level [8], using techniques such as: (i) aggregation of individual judgement for each pairwise comparison into an aggregate hierarchy; (ii) aggregating each individual’s hierarchy and subsequently aggregating the resulting priorities, and (iii) aggregating the individual’s derived priorities in every node in the hierarchy. Techniques (i) and (ii) are known as aggregating individual judgements (AIJ) and aggregating individual priorities (AIP) respectively and are techniques which are of interest in this study.
Aggregating Multiple Decision Makers’ Judgement

**Fig. 2** Flowchart of AIJ aggregation method

AIJ occurs when individuals in a group agree to forgo their individual preferences and act in tandem—essentially merging their judgements to arrive at a synthetic new “individual”. Using AIJ, an individual’s judgement may be revised by the group if said judgment results in too high inconsistencies. This technique does not take into account individual priorities, thus ensuring the Pareto principle is not violated. As this new “individual” needs to satisfy the reciprocity requirement for judgments, only geometric mean can be applied when using AIJ. The weighted geometric mean may be applied to AIJ should the individuals in the group be deemed to be not of equal importance. Figure 2 shows the flow of the aggregation method.

AIP is applied when there is interest in each individual’s resulting alternative priorities. The aggregation happens at the resulting alternative priorities level, using either geometric or arithmetic mean. Similar to AIJ, AIP does not violate the Pareto principle and individuals involved in AIP can also be weighted to indicate different levels of importance. Figure 3 shows the flow of the AIP aggregation method.

The Borda Count (BC) method is another aggregation method by producing an ordering of $N$ alternative ideas, ranked from best to worst. Once every individual in a group ranks all the options in order of preference, the top-ranked idea is awarded a score of $N - 1$, and the last ranked idea is awarded a score of 0. In summary, the $K$-th ranked idea is awarded a score of $N - K$. The BC method has been applied in diverse areas ranging from electoral voting, to decision-level aggregation for multi-modal biometric systems.
BC has been applied [9, 10], to affect hybrid AHP-Borda approaches resolving preferences during decision-making processes involving multiple people. The hybrid AHP-Borda generic workflow is shown below:

a. Perform AHP pairwise comparisons at the criteria or sub-criteria level.
b. Once the AHP weights have been determined, BC is used to rank the alternatives based on the AHP weights given by a person. The alternatives with the highest weight will get \(N - 1\) points, while the lowest weight will be awarded zero points. In the event of a tied weight, a tie-breaker of 0.001 is added from one tied weight and 0.001 is subtracted from the other tied weight.
c. The weights from AHP are multiplied by their corresponding Borda count and are summed up for each alternative. A weight is calculated by dividing the total score for an alternative by the sum of scores.
d. The scores for each person involved in the decision-making process is added to result in an influence index, the more influence a person has on the group decision-making process. Thus, a person who has a high influence on the wrong set of decisions can be moderated in some ways (by means of weight for example) in order to reduce their influence.