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A Comprehensive Review of Uncapacitated University Examination Timetabling Problem

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Abstract

The timetabling problems is the most prominent problem in combinatorial optimization. University Examination Timetabling Problem (UETP) is considered as one of the common university timetabling problems. It involves assigning a set of exams into a certain number of timeslots that are to a certain set of constraints. The timetable of examination is generally generated on central basis in order to facilitate the whole university. The problems in this manner are supposed to be complex because it involves various constraints. Thus, it is a challenging task for both the practitioners and researchers to create a timetable or to conduct a research study respectively. In spite of several techniques reported in the literature have been applied to solve the examination timetabling problem, the final solution is not yet reached. This motivates the researchers to investigate other methods. This paper is a review of the different available techniques in the literature which are used to tackle UETP. Finally, a critical analysis of the described algorithms and their most distinguishing features is presented.

1. Introduction

Scheduling or timetabling is considered as a process of decision making which involves the assigning of the inadequate resources (courses, exams) to tasks (rooms, lecturers) over a particular time (timeslots, periods) which concerns every educational institution, to meet the institutional needs and prerequisites while satisfying the necessities and wants of persons inside the institution (Qu et al., 2009b). Conventionally, a timetabling problem is considered to be as a highly constrained scheduling problem which is applied to the variety of areas with the assigning of limited resources occurring in different activities to meet the required objectives. In many institutions, various practical applications in timetabling problems may be found such as transportation, sport, mineral exploration, communication, aviation, educational institutions and also military (Qu et al., 2009b; Lewis, 2008). There have been growing processes of the researches that contain the construction of timetabling for the sake of educational institutions for the past years. This change occurs due to the complex nature of timetabling that constitutes the increasing number of students and events with the restricted resources such as the limited staff, limited rooms and also timeslots (Qu et al., 2009b; Lewis, 2008). One can categorize the university timetabling problems in two groups of problems (Bykov, 2003): (i) University Course Timetabling Problems (UCTP) and (ii) University Examination Timetabling Problems (UETP).

1.1. Examination Timetabling Problems

The examination timetabling problem is a most common problems that academic institutions are constantly facing. The problem starts when they need to allocate a set of exams to a limited number of timeslots. Carter and Laporte (1996) defined the university examination timetabling problem as:

> "*The assigning of examinations to a limited number of available time periods in such a way that there are no conflicts or clashes*".

The examination timetabling problem is essentially defined as allocating the exams into a limited number of timeslots, while fulfilling the maximum count of constraints which differ greatly from institution to institution. Thus, the examination timetabling problems differ in their size, complexity and constraints (Qu et al., 2009b). In the timetabling literature, two categories of constraints have been presented, namely, the soft constraints and the hard constraints (Alzaqebah and Abdullah, 2014; Carter and Laporte, 1996). These types of constraints are explained as below:

- Hard constraints are those which are not able to violate within any situations. As examples:
  - Two exams cannot be scheduled into one timeslot when there are a number of common pupils sitting for the exam.
  - The count of pupils sitting for the exams should not exceed the number of seats available.

- Soft constraints are those desired to be satisfied, but not absolutely necessary. As examples:
    - Exams which are conflicting are best to be split throughout the examination session in avoiding consecutive timeslots of the exams or two exams on the same day.
    - Exams which are deemed to have the most pupils should be scheduled earliest possible to allow sufficient marking time.
    - Ordering (precedence) of exams is needed to be fulfilled.

A solution to an examination timetabling problem which does not discredit the hard constraints is termed as a feasible timetable. Due to the degree of difficulty in resolving the timetable problem, some of the soft constraints may need to be put aside as it's nearly impossible to not discredit these constraints in generating solutions. Therefore, they are omitted in the objective function (Al-Betar et al., 2010b; Burke et al., 2010a).

In computing terms, examination timetabling is supposed to be a problem related to the hard combinatorial optimization which originates from an NP-hard class for most of its variations. This problem usually incorporates a huge and rugged search space with substantial local optimal solutions. This makes it hard to tackle by the traditional methods (Özcan et al., 2010; Carter et al., 1994).

The university examination timetabling problems are split into the capacitated examination timetabling problems and the Uncapacitated University Examination Timetabling Problems (U-UETP). In this paper, the (U-UETP) will be considered because there are many approaches in the literature used this problem to evaluate their approaches and this problem still an active research domain (Pillay and Banzhaf, 2009; Aldeeb BA et al., 2014b).

1.2. Uncapacitated Examinazation Timetabling Problem (U-UETP)

It has been observed that timetabling problem and its examination may be uncapacitated or capacitated due to the examination's whole consideration. However, only the Uncapacitated University Examination Timetabling Problem (U-UETP) is addressed in this study. This is because the U-UETP does not take into account room capacities while the capacitated examination timetabling problem has to include the hard constraints in a manner that the count of pupils in a particular room that they are allocated to, should not during the period as per scheduled exceed the room capacity (Pillay and Banzhaf, 2009).

Over the last decades, a wide variety of approximation techniques to resolve U-UETP have been established by the Artificial Intelligence (AI) and the Operational Research (OR) communities. An extensive and exhaustive summary of these techniques has been provided by Qu et al. (2009a). Prior establishment based on the graph coloring heuristics methods, assigned exams to timeslots, one by one, based on the level of difficulty. As a recovery approach to the timetable with unscheduled exams, a backtracking method is often used with these techniques. Carter et al. (1996) initiated the main research on the U-UETP by incorporating several graph coloring heuristic methods to U-UETP (Carter et al., 1996). Other studies incorporating the graph coloring heuristic methods for U-UETP are also involved (Burke et al., 2004; Asmuni et al., 2009; Aldeeb BA et al., 2015b).

The main objective for any solvent approach of examination timetabling is to provide a feasible solution with the violations based on the soft constraints with the least numbers which can be remarked here as an "optimal solution". The quality of a feasible timetabling is being optimized using different optimization approaches. In many cases, timetable quality is evaluated by the function with penalty that reflects such degree by which the soft constraints are being violated. As an example, a solution that constitutes a smaller number of violations in the preferences of the examined students such as (the gap between the exams' timeslots are suitable to allow him for well studding) will be evaluated competitive than that with larger number of violations (Aldeeb BA et al., 2014a).

2. Problem description

The UETP are considered as a major administrative concern in many educational institutions. It has been addressed as a difficult optimization problem, in which the amount of computation required to solve the problem increases exponentially with the problem size (Cooper and Kingston, 1996).

The examination timetabling problems are considered as an active research area that has acquired the attention of the researchers of artificial intelligence and operational research fields. It is a NP Complete problem (Cooper and Kingston, 1996; Aldeeb BA et al., 2015a), in which exact approaches are not applicable in finding a (near) optimal solution due to the computational time needed is exponentially increased with respect to the size of the problem.

Several approaches have been adapted to solve the UETP problems. Even so, researchers still interested to find (near) optimal solution for UETP. At the same time, only as far as researchers know Qu et al. (2009b) survey paper reviewed previous studies. Therefore, the researchers find some difficulties and hardship and they need a great effort and time to search and review the previous techniques used to solve UETP. So, this paper presents a broad review of most previous studies that have tried to use approaches to solve the UETP problem. However, due to the availability of a lot of studies on this subject, this paper takes in consideration only one type of UETP which is U-UETP.

3. Representing models for Uncapacitated University Examination Timetabling Problems

The graph coloring and symmetrical bit matrix models are proposed to represent the university examination timetabling problems. The principle of these models is to produce feasible

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solutions without taking into account the soft constraints. The following subsections detail how a timetabling problem can be modelled using these models.

3.1 Graph Coloring

The requirement to construct a feasible timetable to be only clash free is fulfilled, is similar to solving the popular Graph Coloring Problem. A number of research papers, in the last decades have proposed several models and formulations for examination timetabling problem. For instance, de Werra (1985) describes how a graph can be modelled by a problem of timetable. The main aim of graph coloring is to minimize count of colors that can be utilized to color the nodes of graphs as much as possible, by taking into account that none of the adjacent nodes have the same color. The values of colors are known as the 'chromatic number' of graph. This can be linked to the examination timetabling problem, where:

- Each exam is represented by a node.
- The conflict between examinations is represented by the edges between nodes, e.g., the adjacent exams share some students.
- The timeslots are represented by node colors.

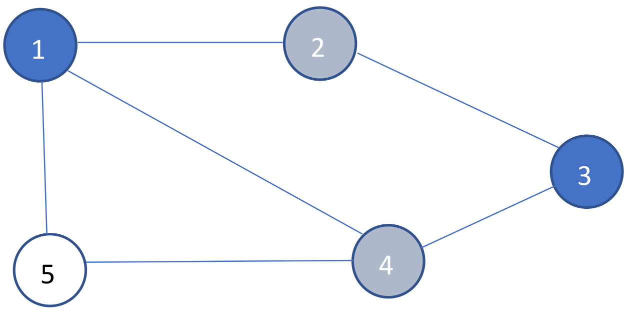

Figure 1: Example of graph G

For example, in Figure 1, UETP is presented using a graph $G = (V, E)$ where, V is the total number of exams (nodes) to be scheduled, and E represents the adjacent exams between each two conflicted exams. In Figure 1, exams 1 and 2 are colored differently because they are adjacent and connected using an edge; this means that these two exams have sharing students. Practically, in this example the examination timetabling solution is represented as a vector: $x = (1, 2, 1, 2, 3)$, which means that exam 1 is scheduled in timeslot 1, exam 2 in timeslot 2 and exam 3 in timeslot 1.

3.2 Symmetrical Bit Matrix

The Symmetrical bit Matrix is another form to represent the problem of examination timetabling. It was proposed by Cole (1964) as a bit matrix which reflects symmetric shape such as $N \times N$ (in which N denotes the number of exams) that contains 1 in the cell i, j, (where $i, j \in \{1, 2\ldots N\}$). In case of any conflict occurring between the two exams i and j; and 0, otherwise (see Table 1), the representations (both matrix and graph) can easily be transformed with each other. The Symmetrical bit Matrix may prove to be helpful when the algorithms are built up for the timetabling problems.

Table 1: Conflict matrix (Cole, 1964)

I* *j	***1***	***2***	***3***	***4***	***5***	***6***	**…**	***N***
1	-	1	1	0	0	1		0
2	1	-	0	1	0	0		1
3	0	1	-	0	1	0		0
4	1	0	1	-	0	1		0
5	0	1	0	1	-	0		1
6	1	0	1	0	0	-		0
…							-	
N	0	1	1	0	0	1		-

In the light of the above, the examination timetabling problem can be considered as a graph coloring problem, in which the goal is to find the minimum timeslots which can contain all examinations without clashes. Some of the earliest works on the formulation of examination timetabling problem such as the graph coloring model can be found in the research studies conducted by Welsh and Powell (1967); Wood (1969); Neufeld and Tartar (1974); Garey and Johnson (1979); Brélaz (1979); Carter (1986); Carter and Laporte (1996); Burke and Ross (1996); de Werra (1996); Burke and Newall (2004). Some of these methods are described in below sections.

4 Techniques applied to Uncapacitated University Examination Timetabling Problems

The U-UETP refers to the assignment of examinations to timeslots in a limit in such a way that it is clash free in terms of between examinations. No conflict refers to the situation where no student is needed to take more than one examination simultaneously. This section describes the methods that used in the literature in tackling U-UETP.

This research intends to review all recent techniques used to solve the uncapacitated university examination timetabling problem were applied on Carter et al. (1996) datasets that comprise of twelve problem instances.

The research reviews the previous studies dedicated to the investigation and development of several optimization algorithms for examination timetabling problems as shown in Figure 2 which have been carried out over the last decades and applied on Carter et al. (1996) datasets that comprise of twelve problem instances (See Table 3). The overview that the research provides is on several techniques represented in the scientific literature that was applied on examination timetabling problems. These techniques were classified by Qu et al. (2009b): Heuristics/Graph Coloring Techniques, Local Search-based Techniques, along with Population-based Techniques, Hybrid Metaheuristic Techniques and Hyper-Heuristic Techniques. The details of these techniques are thoroughly discussed in the next subsections.

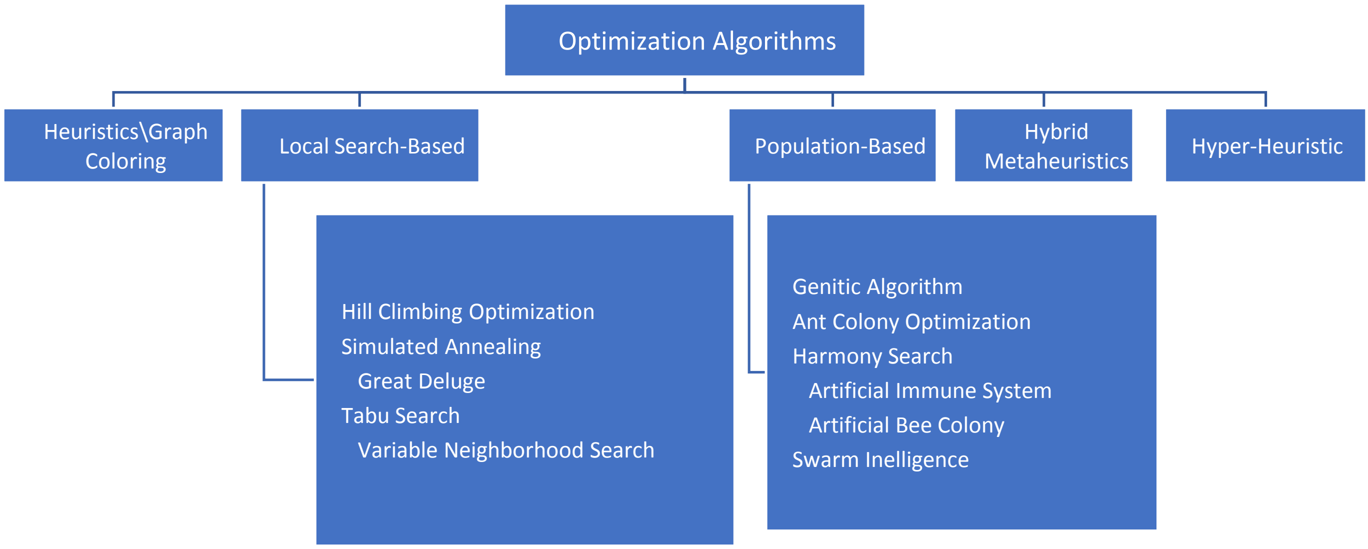

Figure 1: Optimization Algorithms

4.1 Heuristics/Graph Coloring Techniques

An important contribution to the literature of timetabling is the work of Welsh and Powell (1967). These authors' work provides a bridge between timetabling and graph coloring that leads to a latter research of the significant study on the heuristic timetabling graph. There is a need to consider several soft constraints in an evaluated and separate manner in order to provide the measure of solution quality. Therefore, the main weakness of these types of heuristic methods lies on their disability to deal with the soft constraints.

Exams are ordered by the constructive methods which are the basic graphs coloring based timetabling heuristics with the support of their difficulty by which they are scheduled. Prior to this phenomenon of construction, the exams are assigned after one another into their respective timeslots. Ordering strategies with the vast range also their variants modifications become visible in the literature of timetabling (Carter, 1986). Most of the widely employed strategies are based upon the coloring heuristics graph of ordering strategies as presented in Table 2. Another method, called the random ordering method was employed to introduce unpredictability in the hybrid approaches in order to make comparisons.

Table 2: Some ordering strategies based upon graph coloring

Heuristics	**Ordering strategy**
Largest degree (Broder, 1964)	Decrease by the conflicts that several exams have with others.
Largest enrolment (Wood, 1968)	Decrease by several enrolments for exams.
Least saturation degree (Brélaz, 1979)	Increase by several available timeslots for exam in timetable at a time.
Largest weighted degree (Carter et al., 1996; Arani and Lotfi, 1989)	Similar to the "Largest Degree" but weighted by many involved students.
Random ordering (Carter et al., 1994)	Ordering exams with random.
Largest colored degree (Newall, 1999)	Decrease by conflicts that several exams has with particular scheduled at the time.

The heuristics that is based on a graph that is simply underpinned in the constructive methods plays a vital role in the initial phases of timetabling research (Carter, 1986). Further, although being adapted and employed they are still with the hybridized methods which are originally the techniques that exist in their own right in the existing literature researches. The great strength they can provide is that they are able to provide good rationale outcomes within a little time of computation, and techniques are much easier to implement. Initial solutions are often constructed through these graphs or the big portions of solutions can be built in a good manner prior to the application of the improvement techniques (Yang, 2004).

The influential research was particularly studies with the initial five strategies of ordering (Carter et al., 1996) as shown in Table 2 on random and real generated examination problems for timetabling. Largest sub graphs are often referred as largest cliques where each vertex is adjacent to others that constructed the initial solutions. Those cliques were based on the graph coloring backtracking and heuristics techniques that were employed to construct and identify the solutions. Behind this idea, the largest cliques was determined the least of those timeslots which were needed to solve the problems. The outcomes showed that none of the heuristics outperformed any of the other problems on the overall basis that was tested. Establishing a set of 13 problems related to timetabling problems is another contribution which seems important from this work that turn into the defacto benchmark within the field. These have been used widely to investigate the various approaches in the duration of several years (see Table 3). Carter and Johnson (2001) investigated sub-graphs which are sufficiently dense on total of eleven of such instances. It was felt that in the real problems regarding timetabling examination the case was that presence of most mechanisms and many largest cliques can be extended potentially in order to improve the aforementioned approach.

The adaptive strategy of ordering was investigated by Burke and Newall (2004). In particular, the authors ordered the exams dynamically when the problems are solved in a particular iterative process. A fixed pre-defined heuristic was observed (that were employed as a determinant of complexity) within a sequential traditional strategy as per Table 2. This strategy, which is related to tradition always does not perform a sound well over the problems of all ranges. In order to update the exams ordering a heuristic modifier was designed in accordance with the experience which was obtained with regards to assigning difficulties in the preceding iterations. Widespread experiments were supposed to carry out on the 11 of the Carter et al. (1996) datasets and other related benchmarks. The comparison of this approach was identified to be effective and simple with the occasions that were more competitive than any state-of-the-art approaches. However, this method does not rely on the initial exams' ordering.

Table 3: Techniques applied to Carter et al. (1996) datasets

No.	**Reference**	**Approach**
1	(Carter et al., 1996)	Graph heuristics with clique initialization and backtracking.
2	(Burke and Newall, 2004)	Graph heuristics with adaptive heuristic.
3	(Yang and Petrovic, 2005)	Great Deluge and graph heuristics.
4	(Qu and Burke, 2005a)	Variable Neighborhood Hyper heuristic.
5	(Asmuni et al., 2007b)	Fuzzy evaluation function with multiple criteria.
6	(Qu and Burke, 2009)	Graph based hyper-heuristic.
7	(Asmuni et al., 2009)	Fuzzy heuristic ordering model.
8	(Pillay and Banzhaf, 2009)	A study of heuristic combination approach.
9	(Qu et al., 2009a)	A graph based hyper-heuristic.
10	(Sabar et al., 2012b)	Graph coloring constructive hyper-heuristics.
11	(Rahman et al., 2014)	Adaptive linear combinations of graph coloring heuristics.
12	(Xu et al., 2014)	Graph coloring.
13	(Burke et al., 2014)	Hybridized hyper heuristics with improvement low-level heuristics.
14	(Abdul-Rahman et al., 2014)	Adaptive decomposition approach.

No.	Reference	Approach
1	(Côté et al., 2005)	Hybrid Multi-Objective Evolutionary.
2	(Eley, 2007)	Ant colony algorithms with hill climbing operators.
3	(Turabieh and Abdullah, 2011b)	Hybridization of electromagnetic-like mechanism with great deluge.
4	(Alzaqebah and Abdullah, 2011c)	Disruptive Artificial Bee Colony.
5	(Alinia Ahandani et al., 2012)	Hybrid Particle Swarm Optimization.
6	(Bolaji et al., 2012a)	Modified Artificial Bee Colony algorithm.
7	(Abdullah and Alzaqebah, 2013)	A hybrid self-adaptive bees algorithm (self-adaptive DBA).
8	(Sabar et al., 2012a)	Honey-bee mating optimization algorithm.
9	(Abed and Tang, 2013)	Hybridizing Genetic Algorithm and Record-to-Record Travel Algorithm.
1	(Di Gaspero and Schaerf, 2001)	Tabu Search algorithm.
2	(Paquete and Stützle, 2002)	Tabu Search with Lex-tie and Lex-seq strategies in the objective function.
3	(Di Gaspero, 2002)	Multiple neighborhood Tabu Search.
4	(Merlot et al., 2003)	Simulated Annealing and Hill Climbing.
5	(Casey and Thompson, 2003)	GRASP local Search-based Method.
6	(Burke and Newall, 2003)	Great Deluge with adaptive ordering.
7	(Burke et al., 2004)	Time-predefined Great Deluge and SA.
8	(Yang and Petrovic, 2005)	Similarity Measure for Heuristic Selection.
9	(Abdullah et al., 2007b)	Tabu Search based large neighborhood search.
10	(Eley, 2007)	Ant Colony algorithm.
11	(Pillay and Banzhaf, 2010)	Genetic algorithm.
12	(Burke et al., 2010a)	Hybrid variable neighborhood algorithm.
13	(Al-Betar et al., 2010c)	Harmony Search Algorithm.
14	(Abed and Tang, 2013)	Genetic algorithm.
15	(Al-Betar et al., 2014)	Memetic algorithm.

The heuristics and graph coloring techniques are used to solve the problem of university examination timetabling by applying these techniques to some real-world benchmarks (Hussin et al., 2011; Kahar and Kendall, 2010). The real world that were being used were Multimedia University and Universiti Malaysia Pahang in Malaysia, in these studies, the authors used heuristic approaches which included graph coloring, cluster heuristic and sequential heuristic to solve the examination timetabling problems in such universities. Based on the experiments from the studies, the graph coloring heuristic is suitable for the problem that focuses on the hard constraint, but it is difficult to solve the soft constraints.

The graph coloring's constructive hyper heuristic approach was investigated by Sabar et al. (2012b) for solving the examination timetabling problems. Here, the hierarchical hybridizations which consist of four low-level graphs of coloring heuristics were utilized by the authors. These investigations also included several degrees which are; saturation degree, largest enrollment, largest degree, and colored degree. In the process, the graphs are hybridized in order to produce four lists of orders. They included a roulette wheel selection mechanism to probabilistically select an appropriate timeslot for the chosen exam to improve the timeslot selection's effectiveness. In that duration, the most widely used uncapacitated Carter benchmarks were tested by the authors with the help of those proposed approaches. They also tested the approach on the recently introduced examinations and on the datasets of timetable in 2007 in the event of the International Timetabling Competition. If the approaches are compared to other methodologies for this author, the outcomes obtained from the graph coloring's constructive hyper heuristic are good outcomes, and further approaches could be outperformed on some instances of benchmark.

Abdul Rahman et al. (2014) addressed the examination timetabling problem by investigating the adaptive linear combinations related to graph coloring heuristics along with a heuristic modifier. They invoked a normalization approach in order to simplify the data of the specific problem for each parameter. Two graph coloring heuristics were used in the following study (saturation and largest degree). The multiple along with the single heuristics were tested by the authors by testing both approaches with and without a modifier. These approaches were tested in several aspects of combinations of values of weights with every parameter on the ITC2007 and the Carter et al. (1996) benchmark datasets. The authors, while examining the effects of such approaches observed the phenomenon of combination of several heuristics to offer an effective path with a heuristic modifier in order to attain the quality of a good solution. The outcomes attained from the experiments demonstrate that the approach provides potential outcomes. Based on the outcomes, the authors also deduced that the heuristics linear combination is supposed to be an extremely effective method for the simple and easy implementation.

Table 4 summarized the heuristics/graph coloring techniques in the literature that applied on university timetabling problems.

4.2 Local Search-based Techniques

Local Search-based Techniques is an iterative process which is often called a single point technique or a single solution technique. By the application of local changes, it can move from one solution to another until or unless it finds a solution deemed optimal or elapsed a time bound. To tackle many timetabling problems, various local search based techniques for instance, Great Deluge, Variable Neighborhood Search, Simulated Annealing, Hill Climbing and Tabu Search have been utilized successfully (See Table 2.3).

Hill Climbing Optimization (HCO)

The Hill climbing Optimization (HCO) explores a very limited portion of the search space where it only accepts an improved move. This algorithm begins by the help of an initial solution. The algorithm applies a move to generate a new solution. In case an improvement is there in solution quality, then the new solution replaces the current one (Burke and Newall, 2003).

The drawback of this procedure is that, it can be easily trapped at local optima. In order to overcome this drawback, many researchers have modified and hybridized this approach with other approaches, such as (Burke et al., 1996).

Merlot et al. (2003) applied a three phases approach where in the first phase, a constraint programming technique is utilized in generation of initial solutions. Considering the second phase in which the simulated annealing with a Kempe chain neighborhood structure is employed. Later, the HCO approach is applied in the third phase in order to further improve the solution quality obtained from second phase. This approach is able to produce some of competitive outcomes for the University of Nottingham datasets and Carter et al. (1996) datasets at that time (Qu et al., 2009b).

Burke and Bykov (2008) modified the HCO by proposing a late acceptance hill climbing. This approach executes to iteratively improves it and with a single solution. The fitness values are kept by the algorithm post to each move with a particular size in a list. Based on comparison a fresh solution will be accepted between previous and new solutions in list. Good quality outcomes can be produced through this research on Carter et al. (1996) datasets (12 "Uncapacitated with cost"). Most of the outcomes obtained by this approach are competitive than recent popular outcomes in literature. This approach has drawbacks in which the performance is mainly related to the size of the list, different datasets have different size settings; the authors gave a custom size for each dataset, this can give competitive solutions. On other hand, the authors also gave a general setting of the list size which can bring comparative outcomes on the similar dataset.

Alinia Ahandani et al. (2012) proposed a method for solving examination timetabling problems mainly based on swarm optimization and two phases hill climbing local search operators, the obtained outcomes demonstrate that the proposed HCO local search produced good outcomes.

Bykov Y. and Petrovic S., (2016) offers a new simple method which is a single-parameter local search heuristic called "step counting hill climbing algorithm"(SCHC). The simplicity of this method is in the current cost helps as an approval bound for a number of repeated steps. This is consider as the only parameter in the approach which must set up by the operator. Also, the counting of steps could be arranged in several ways; consequently, the suggested approach produces a big number of extensions and also alternatives. Their research explore the performance of the three main variants of SCHC at the exam timetabling problem at university level. The trials show that the suggested approach shares the basic features with the late acceptance hill climbing method, specifically its convergence time is comparative to the significance of its a non-linear rescaling and parameter of a problem has no efficacy on its search performance. Moreover, there are two advantages of the suggested approach: enhanced overall performance and more flexible acceptance condition. The current study compared the new approach with late acceptance hill climbing, both algorithms SA and GD. The SCHC presents the best performance on the majority of datasets used.

Simulated Annealing (SA)

Simulated Annealing (SA) algorithm was introduced by Kirkpatrick et al. (1983). It is exploited from the analogy of physical process where a phenomenon of heating of a metal at a high temperature and cooled off into a crystalline structure and no more can be changes occur. SA has the capability to ignore at local optima in being trapped. It assigns a random search that accepts not only the positive changes but also negative changes with certain probability range.

To elaborate SA starts from an initial solution that is randomly generated. The neighbor or candidate solution which is also generated at random will always be recognized if it is good as compared to the current one, while a specific probability accepted with a worst neighbor which the Boltzmann probability P determines, with the help of the formula which is $P = e^{-\alpha/t}$ where a is the difference of current and candidate solution quality, and t is a control parameter which is known as a temperature. The temperature is decreased over time according to a cooling schedule (Aarts and Korst, 1988).

Merlot et al. (2003) employed simulated annealing approach that was initialized on the basis of techniques of constraint programming. It was followed by hill climbing in order to improve further solution. It was also employed a neighborhood of modified Kempe chain. With the support of this hybrid approach, competitive outcomes were achieved at the time of different instances of the benchmark. As usual, still the method has most of the famous outcomes. As suggested by the author, these methods combine the solution construction along with ordinary search that will govern the examination timetabling future in further researches.

SA was employed by Duong and Lam (2004) on initial solutions that were generated by the constraint programming for problems of examination timetabling at University named HoChiMinh City University of Technology. A neighborhood of Kempe chain in Simulated Annealing was employed which experimentally set its cooling schedule by using algorithms and mechanisms. It was noted by author that when there is a limited time provided, it becomes crucial and difficult in tuning SA components to which the specific problems are to be solved.

Similarly, variant of SA was studied by Burke et al. (2004) that is now called "Great Deluge Algorithm". Worse moves were accepted by the search as long the quality is decreased that is supposed to be below to a particular level. The level is basically set originally as the quality of gradually lowered and the initial solution by a decay factor. Parameters are represented by the estimate and a decay factor of desired quality in this approach. These parameters can set out by the users. These users are not generally the experts on Metaheuristics. However, the initial solutions are needed to be feasible to examine the decay factor. In this way, a saturation degree can be run with a more times. The best solutions could be employed from the calculation of decay factor similar to starting points. This approach i.e., "Great Deluge Approach" was finer to a SA method. It was proved to be effective. Also, it generated the competitive outcomes on the Nottingham datasets and Carter et al. (1996) as compared to the other approaches. In order to analyze a particular trade-off, it carried out the comprehensive experiments. The trade-off will be analyzed between solution quality and time on several problems with multiple sizes. Furthermore, the approach was studied also by Burke and Newall (2003) where the initialize was done using several ordering adaptive methods in (Burke and Newall, 2004).

Cheraitia M. and Haddadi S. (2016) applied a simple graph colouring heuristic in order to create a feasible timetable in order to begin with. In the process of improving the spreading of conflicting exams, researchers have used SA as an iterative heuristic. The results showed that the proposed method provides competitive results compare to the state-of-the-art. The UESP, for which a metaheuristic is designed. Begin with a first placement obtained by using a simple graph colouring heuristic, the SA algorithm was used for iteratively improving its quality. Three distinct neighborhoods are proposed concurrently for search, and a robust geometric cooling schedule is designed for controlling the temperature change. The results obtained on a set of benchmark instances and the comparison from two points of view with 10 recent methods show that the proposed method was competitive with the state-of-the-art. The main conclusion was that the SA algorithm, although time consuming, still remains a good tool, when well controlled, for tackling hard combinatorial optimization problems.

Leite N. et al. (2019) presents new variant of the Simulated Annealing algorithm, named FastSA. In the presented approach each exam selected is only shifted if the stated exam had any approved shifts in the directly preceding temperature bin. Ten temperature bins were created, FastSA confirmed that an equal number of evaluations is performed in each bin. The proposed method was observed that the exam likely have few or zero accepted movement in the future if it obtain zero accepted movement in the preceding temperature bin. The presented FastSA and the standard Simulated Annealing methods were applied on the second International Timetabling Competition (ITC 2007) benchmark. On the other hand; the Simulated Annealing, the FastSA uses a maximum of 41% less evaluations on one dataset and 17% less evaluations. Based on the solution cost, the proposed method is competitive with the Simulated Annealing methods attaining the most accepted average fitness value in four out of twelve datasets, whereas it consumes time compared to others. The study main impact comprises the points: (i) demonstration of the proposed method capabilities on a NP-Complete timetabling problem, (ii) proposal of a proposed method which is able to reach a reduced computation time compared to the standard Simulated Annealing, (iii) comparison with state-of-the-art methods where the FastSA is able to improve the best known result on a benchmark instance.

Great Deluge Algorithm (GDA)

Dueck (1993) introduced the great deluge algorithm. It assumes to be an alternative to SA which is less parameter dependent. It requires two parameters i.e., computational time and the estimation of a solution quality. A competitive solution is accepted by algorithm and for a worse solution if it is equal or less than a value of boundary it is accepted which is referred to level.

In the beginning, the levels are set out by the algorithms as initial solution quality. During the search, the level is updated based on a constant which is referred to a decay rate. Burke and Newall (2003) applied the great deluge with adaptive ordering as the initialization on the Carter et al. (1996) datasets. The adaptive ordering method is taken from Burke and Newall (2004). The water level in great deluge is decreased by referring to a predetermined rate. In that research, the authors have conducted a comparison between simulated annealing, HCO and great deluge. The great deluge algorithm performance is shown to be the best in comparison with HCO and SA. This approach can produce competitive outcomes on the Carter et al. (1996) datasets as compared to competitive outcomes that the literatures reported at the time.

The work presented in "Solving examination timetabling problems through adaption of heuristic orderings" by Burke and Newall (2004) has implemented the graph heuristics with adaptive heuristic modifier to order the examinations dynamically. This approach is used to construct the initial solutions. It is applied on Carter et al. (1996) datasets (11 "uncapacitated with cost" and 3 "capacitated with modified cost"). This approach is shown to be simple and able to improve the solution quality substantially more than the basic heuristics, i.e., smallest degree, flat ordering, and largest degree.

Burke et al. (2004) implemented a time predefined SA and great deluge algorithms. The decay rate is defined as a difference between the current solution quality and the desired solution quality over time. The time predefined great deluge algorithm is measured as effective. It generated some of the competitive outcomes on the University of Nottingham and the Carter et al. (1996) datasets. The tested Carter et al. (1996) datasets are 13 "Uncapacitated with cost" and 2 "capacitated with modified cost".

Yang and Petrovic (2005) applied a measure of similarity with the utilization of a fuzzy set in choosing hybridizations of great deluge and graph heuristics. The performance of such approach is competitive than the single great deluge and is also able to attain competitive outcomes compared with other outcomes reported in literature for some Carter et al. (1996) datasets (12 "Uncapacitated with cost").

An evolutionary non-linear great deluge algorithm was presented by Obit et al. (2011) in order to solve the problems of university timetabling. In this method, individuals are selected with the help of selection ion tournaments. They are also improved by using an operator known as mutation operator. In order to find out an improved individual, who is supposed to be competitive than any other individual, one has to replace him among the population. Great quality outcomes can be attained by the process of hybridization between evolutionary operators and non-linear great deluge as shown by the most outcomes by experiments. This approach is same as the approach in Turabieh and Abdullah (2011b) which an integrated hybrid approach is employed, which is a hybridization related to electromagnetic-like mechanism and great deluge for examination timetabling problems. Hybridization is claimed as a dynamic approach, where the expected quality of a new solution and the decay rate are calculated in each iteration method. The authors have stated that by using a dynamic decreasing rate, the approach is able to find competitive examination timetabling solutions. The approach is applied to the Carter et al. (1996) datasets (12 uncapacitated datasets). This approach is shown to be simple and effective, and able to produce a number of famous outcomes in comparison with state-of-the-art approaches.

An extended and modified GDA was introduced by Kahar and Kendall (2013) for the problems related to the examination timetabling. Several initial solutions were investigated by the authors which the GDA taken as a beginning point. Additionally, it also was utilized in the work of altering of the iterations. A sort of statistical analysis was carried out in order to compare the outcomes where these unique parameters with several natures are used. The methodology used in this study could provide competitive outcomes for the quality solutions as compared to other solutions that host organizations provides.

Acan and Üveren (2014) maintained a two-stage memory architecture and search operators within the framework of a GDA for real-valued global optimization. The level-based acceptance criterion of the GDA is applied for each best solution extracted in a particular iteration. The use of search based on memory is supported by effective move operator outcomes in a powerful optimization algorithm. The success of the presented approach is illustrated using three sets of well-known benchmark functions including problems of varying sizes and difficulties. Performance of the presented approach is evaluated and in comparison to well-known algorithms and their published outcomes. Except for a few large-scale optimization problems, experimental evaluations demonstrated that the presented approach performs at least as good as its competitors.

MN M. Kahar and G Kendall (2015) investigated a real world problem. They introduced a modified and extended GD method to tackles timetabling problem which applied a single, easy to understand parameter. They investigated new initial solutions that used as an initial solution for the GD algorithm. In addition to altering the number of iterations. On the other hand, they compared the outcomes by using these parameters. The suggested approach has the ability to generate competitive solutions when compared with the solution currently produced by the host organisation.

Tabu Search (TS)

Tabu Search algorithm was proposed by Glover (1989). Details of this approach can be found at (Laguna and Glover, 1993; Gendreau and Potvin, 2005). Basically, the idea of this tabu search algorithm is to study the search space by keeping the last n visited solutions in a tabu list to avoid duplicating search on those solutions while producing new solutions. However, this approach aims to escape from local optima and force the algorithm to consider new regions of space. The drawback of this approach is that the parameters (i.e., stopping criteria and tabu list) need to be tuned and this is very much related to the problem (Gendreau and Potvin, 2005).

Di Gaspero and Schaerf (2001) employed the cost function and adaptive tabu list in tabu search for examination timetabling problems. The authors used a dynamic tabu list size, in which the tabu list size is adaptively set during the search. For the purpose of finding the most significant moves (neighborhood moves) at each iteration, this approach proposed exhaustive and biased selection strategies to select each single move among the examinations. This approach is tested on the University of Nottingham datasets and Carter et al. (1996) datasets (three capacitated with modified cost, five capacitated with cost and eleven uncapacitated with cost datasets). This approach employs a much bit successful outcomes.

Di Gaspero (2002) developed a multiple neighborhood tabu search approach where a multiple neighborhood based on token-ring search is applied. This approach has been applied on Carter et al. (1996) datasets (three capacitated with modified cost and seven uncapacitated with cost). The outcomes of this approach was good and competitive.

Tabu search with a long term memory approach was employed by White and Xie (2001) for examination timetabling problems using fabricated dataset for the University of Ottawa. This is a four-stage tabu search approach called OTTABU, which uses a short term memory and long term frequency, in order to keep the most active moves frequency during the search.

In White et al. (2004), a relaxation on short and long term tabu lists was proposed, where the size of the two lists can be relaxed dynamically without any improvement post to a particular period of time. This approach is applied on Carter et al. (1996) datasets (seven Uncapacitated with cost).

Paquete and Stützle (2002) applied a tabu search approach for examination timetabling problems. Both soft and hard constraints are ordered based on priorities, in which hard constraints have highest priority compared to soft constraints. Two strategies are employed to deal with constraints referred as "lex-seq" and "lex-tie" strategies. The "lex-seq" strategy represents the sequential optimization that tries to satisfy the constraints in decreasing order i.e., start with the highest priority to the least priority provided that the higher priority constraints are not violated. While in the "lex-tie" strategy, solutions are compared by the cost value of the higher priority (in case of a tie, the solutions are compared using the next lower priority). Outcomes generated by experiments reveal that lex-tie strategy is able to obtain good outcomes on some Carter et al. (1996) datasets.

Abdullah et al. (2010) employed a hybridization between tabu search and memetic algorithm. The unperformed neighborhood structure is inserted in the tabu list for a certain number of iterations before it is available to be employed again. The tabu list is introduced in order to control the selection of the neighborhood structures. This approach is tested on Carter et al. (1996) datasets (eleven uncapacitated with cost) and able to obtain competitive outcomes than some of the best-known results in the literature.

Variable Neighborhood Search (VNS)

Variable neighborhood search deals in applying a number of neighborhood structures n in order to escape local optima by systematically changing from one neighborhood to another based on the search status (Mladenović and Hansen, 1997). The intensification in this approach is obtained by a local search and the diversification is realized on a systematic change of neighborhood structure (Hansen and Mladenović, 2001).

Variants of "Variable Neighborhood Search" were investigated by Burke et al. (2006a). These authors also obtained best outcomes in the literatures across most of the problems in Carter et al. (1996) datasets. By utilizing Genetic Algorithm with standards, the outcomes were improved further by selecting a subset of neighborhoods intelligently. There is a strong link of latter approach with the work in hyper heuristics. The latter approaches indicated the promising directions on the development of more approaches, in general, on the neighborhoods as compared to directly developing the solutions. "Variable Neighborhood Search" was also employed in hyper heuristics when a search of graph heuristics as compared to the neighborhoods occurred (Qu and Burke, 2009).

A large neighborhood search was developed by Abdullah et al. (2007a) this particular search was based on the methodology in order to improve on original basis the graph construction developed by Ahuja et al. (2001) for different problems of optimization. Instead the operators based on traditional pair wise exchange was just to be considered, designing a neighborhood structure based on shape of tree was done in order to bring over a cyclic exchange among most timeslots. The best outcomes were provided by these approaches on most problems of Carter et al. (1996) dataset when there is a time of publication. However, there was a need of computational time in a big extent. It was developed further in Abdullah et al. (2007b) where moves respect to improvement was kept in tabular lists for timetabling problems of capable examinations.

Burke et al. (2010a) proposed a variable neighborhood search metaheuristic for Carter et al. (1996) datasets (eleven uncapacitated with cost). The goal here was to prove that the proposed technique is capable of producing good quality solutions over a number of benchmark problems. The hybridization with a genetic algorithm which intelligently selects which neighborhood structures to be used for a specific problem is demonstrated to be very successful. As shown in Table 4, it can be summarized that during last decades, the technique which have been studied very heavily is local search based technique. It also obtained a finer capable success in the field of timetabling. All discussion in the above sections based on work which was either tested on benchmark data. There are different ways to accept the moves such as acceptance strategies, moving strategies and also selection strategies that were studied in the past. The objective was to enable escape from the local optima. However, the only significant drawback from these approaches is that effort which is required to adjust the parameters for particular problems in order to attain high quality solutions to those problems.

4.3 Population-Based Techniques

These techniques are classified as stochastic algorithms which initializes along with a population of solutions at a particular time. A strategy is applied, iteratively to choose the update solution in population then, generating the new solutions that include the new population (Deb, 2005). Genetic Algorithm is the most tailored population based technique (Jha, 2014; Innet, 2013Pillay and Banzhaf, 2010; Terashima-Marin et al., 1999; Ross et al., 1998; Erben and Keppler, 1996; Ergül, 1996). Other techniques are Ant Colony Optimization (Thepphakorn et al., 2014; Lewis, 2008; Eley, 2007; Merlot et al., 2003), Harmony Search (Al-Betar et al., 2010b), Artificial Immune System (He et al., 2005; Malim et al., 2005), Artificial Bee Colony (Alzaqebah and Abdullah, 2014; Abdullah and Alzaqebah, 2013; Alzaqebah and Abdullah, 2011a,b) (See Table 4).

Genetic Algorithm (GA)

This technique was introduced by Holland (1975) initially which was based on the concept in which new individuals are generated from the present members of population. Genetic Algorithm is a type of population-based metaheuristics technique. Chromosome that consists of genes represents each individual that constitutes a key attribute of an individual (Goldberg, 1989). In this technique the initial steps begin with evolving population of individuals in its overall fitness that may improve the iteration over the time. The overall fitness is the sum of the fitness of individual solution.

A cross-over operator based on cliques was designed by Terashima-Marín et al. (1999) based on problems of timetabling that took the shape of the graph coloring problems. Strategies of several combinations were tested in the processes of reproduction in which the cliques were transferred from parents to their progeny. Similar problem was pointed out directly by the same author (Ross et al., 1998) with Genetic Algorithm representation as mentioned in the above sections. Substitutes were suggested for the upcoming plane and to implement it in the future. Penalty function was also studied in both real and random problems of timetabling which employed the theory of Hardness (Terashima-Marín et al., 1999). The prediction of the theory is to point out the position of hardest instances of the problems of timetabling. They observe that in guiding Generic Algorithms, the addition of this measure will not prove to be helpful toward search space promising areas. Non-direct coding was also investigated by the authors in Genetic Algorithms (Terashima-Marín and Ross, 1999). In this coding, the strategies related to heuristics and construction of solution as compared to actual solutions was coded. For instance, dealing of heuristic with constraints, assigning of nodes in ordering and methods of satisfying constraints were coded in this approach. Potential outcomes that are attained by these approaches on Carter et al. (1996) datasets reflected the non-direct representation in Genetic Algorithms.

The issues related to the Genetic Algorithms and its implementation was investigated and discussed by Wong et al. (2002) in order to solve many problems regarding timetabling of examination at Ecole de Technologie Superieure. Those issues were recognized as the problem for constraint satisfaction. Selection of tournaments was utilized to pick parents. Mutation incorporated the repairing strategies for the purpose of producing good candidates for the exams. Furthermore, bi-objective evolutionary algorithm was investigated by Côté et al. (2005). The objective of that investigation was to provide space to conflicts in exams and also to minimize the length of timetable. Classic Tabu Search and a modified Variable Neighborhood Descent referred to as local search operators were employed instead of recombining the operators with the soft and hard constraints. Hence, this method attaints the competitive outcomes on large figure problems regarding benchmark as compared to some literature approaches (e.g. (Carter et al., 1996; Burke et al., 1996; Merlot et al., 2003)). The review was also provided by author on state-of-the-art approaches on Carter et al. (1996) datasets at the time.

Informed genetic algorithm with two stages was proposed by Pillay and Banzhaf (2010) for the examination timetabling problems. In the very first phase i.e., initial phase the central point for this algorithm was to prepare a sufficient timetable with no errors which will be used to convince overall hard constraints. On the other hand, in the second phase algorithm will take into account the process of minimizing violations of soft constraints. Genetic Algorithm in those two phases was utilized to prepare the timetable along with its improvement. Equivalent outcomes were attained on Carter benchmark datasets over other several methods. The author did not propose the rationale to utilize GA in improvement and construction phases. This behavior of author increased the parameters count and evaluated time which is required to get tuned. In addition, worse outcomes were found as compared to others.

An adaptive model of Genetic Algorithm was presented by Innet (2013) in order to improve the effect of examination timetable and its arranging occurs automatically. Soft and hard constraints were discussed by the author for this particular problem. Moreover, penalty cost function was presented along with the designing of genetic elements. Crossover operator, mutation operator as well as selection operator related to genetic algorithm was employed in this model. In order to attain some outcomes, a simulation was deported. The outcomes in this manner reveals that model of Genetic Algorithm is essential to arrange the examination timetable. Hard constraints were not appeared with about 75% cross over rate in timetable.

A recent genetic application to examination timetabling was investigated by (Jha, 2014), the author used genetic algorithm for solving the problem of examination timetabling. This paper details the implementation of a computer program which employs genetic algorithm for an optimal solution of solving a timetable problem and generate examination timetable by using real student data from engineering department courses at Information and computer technology.

Ant Colony Optimization (ACO)

Ant Colony Optimization (ACO) was presented by Dorigo and Gambardella (1996). This algorithm imitates in the colony of ants, their foraging behavior. A path joining the food source and nest are constructed by this colony. Pheromones are deposited by the ants on the path from the nest to food source. Pheromone paths are navigated then, towards food or nest used by ants with the help of deposited pheromones along the path. With the increase in the pheromone's density, ants also increase to follow the path. In this way, the high density paths as compared to others are more attractive for ants.

A comparison of Tabu Search, SA, and Genetic Algorithm with ACO system was implemented by Azimi (2005) in order to solve the examination timetabling problems. Heuristically, early solutions were produced for ACO system that afterwards cleared by the local search. Over the running time, the outcomes illustrated that performance under the approach of ACO was greatest and highest improvement was found in the Tabu Search upon random solutions. Post to the experiments of these approaches, three variants on hybridization were studies on ACO and Tabu Search in (Naji Azimi, 2005). It was noticed that approaches of hybrid performed competitive than any other algorithm. Also, the sequential ACO that Tabu Search follows attained the best outcomes. Instead, the data to test those algorithms was used which generated randomly.

ANTCOL and Max-Min was coded as two approaches investigated by Eley (2007) by proposing Ant algorithms for examination timetabling problems. Hybridization between hill chamber and a simple ant system was made in both approaches. The construction of initial solution was also occurred on the basis of saturation degree metaheuristic inverse. The ANTCOL outperformed, with hill chamber, the hybrid Max-Min Ant system. The parameters were also found affecting the tasks of approaches by the author sitting in ant system. The approaches were tested on Carter et al. (1996) datasets (13 uncapacitated with cost).

Metaheuristic algorithms have been surveyed by Lewis (2008) that applied to both exam and course of the university problems related to timetabling. On Tabu Search, colony optimization and also on evolutionary algorithms the author concentrated on high priority. The review of the literature was occurred in three multiple categories; one-stage and two-stage optimization algorithms and last is algorithms allowing relaxations. Research study also carried out a part of analysis along with the emphasis on soft and hard constraints which were addressed further. The value of the benchmark data was also pointed out by the author in research belongs to examination timetabling.

Recently, Thepphakorn et al. (2014) developed Ant Colony based approach for solving university timetabling problems. the authors embedded New variants of Ant Colony Optimization (called the Best-Worst Ant System (BWAS) and the Best-Worst Ant Colony System (BWACS)) in the ant colony timetabling program and they developed and embedded Local Search strategies into BWAS and BWACS to improve their efficiency and to help find the best solution with the lowest soft constraint violations. 8 benchmark problems were used for evaluating the performance. The BWACS produced the best timetable for large problems and it was competitive than the other ACO variants. The best proposed local-search technique improved the performance of both (BWAS and BWACS).

Khair A. F. et al. (2018) presented the latest approach using an ACO which is the ant system (AS) to find an effective solution for dealing with university exam timetabling problems. The key of this feature is to simplify and find shorter paths based on index pheromone updating. With appropriate algorithm and using efficient techniques, the schedule and assignation allocation improved. The proposed method applied to the data set instance that has been gathered. Therefore, performance evaluation and result are used to formulate the proposed method. This is to determine whether it is reliable and efficient in managing feasible final exam timetables for further use.

Artificial Immune System (AIS)

Nature Immune system inspired AIS (Artificial Immune Systems). The processing of strong information with the capabilities of the immune system offers metaphors for its artificial counterpart (Dasgupta et al., 2003). The capabilities of this immune system include; learning, distributive nature, pattern of recognition, memory and feature extraction. Malim et al. (2005) presented three artificial immune algorithms for examination timetabling; immune network, clonal selection and also the negative selection. They compared the effectiveness of the algorithms on examination timetabling problems. The experimental outcomes, using datasets revealed that all algorithms have successfully produced good examination timetables on all Carter et al. (1996) datasets. The clonal selection and negative selection algorithms are more effective than immune network algorithm in producing good quality examination timetables; however, the immune network algorithm runs faster than clonal selection and negative selection.

Artificial Bee Colony (ABC)

The ABC algorithm was originally developed by Karaboga (2005) as a global optimization algorithm in which the honeybees foraging behavior is simulated. The algorithm has been employed and modified by many researchers as in (Karaboga and Basturk, 2007, 2008; Karaboga, 2009; Kang et al., 2009). ABC algorithm consists of three groups of agents (scout, employee and onlooker bees). They cooperate and communicate with each other through a waggle dance to find a good solution.

ABC algorithm tested on examination timetabling problem with incorporation of large neighborhood structure by Alzaqebah and Abdullah (2011a) and SA was hybridized within the onlooker bee for the same problem (Alzaqebah and Abdullah, 2011b). ABC techniques provide such outcomes within which the previous techniques were produced in literatures. Selection of sites as compared to the use of fitness value was proposed by Abdullah and Alzaqebah (2013) with the help of three techniques. These techniques improved the population diversity. For the purpose to turn the neighborhood search into direct, a self-adaptive strategy can be added to increase the capability of local intensification. A modified bee's algorithm was combined by the author along with the local search to urgent declining of the optimum solution. Outcomes that can be adopted by the experiments, proposed the modification phenomenon with one another. In this regard, basic BA reveals that it outperformed the basic modification. On two datasets of examination timetabling, a whole comparison was determined with the finest known outcomes. This identified the approach to be competitive and recognized as performing well in all works in all instance problems.

A disruptive selection strategy was applied by Alzaqebah and Abdullah (2014) to ABC algorithm that implies to improve the population diversification. Premature convergence can also be prevented in such evolutionary processes. Furthermore, the addition of self-adaptive strategy for the selection of neighborhood structures was done to increase the capability of local intensification. ABC algorithm in a modified condition was hybridized by the author along with a local search algorithm. ABC algorithm outperformed, along with the disruptive self-strategy, as revealed by conducting some experiments the original ABC algorithm. The lone ABC algorithm was also outperformed by the hybridized ABC algorithm during the test of examination timetabling problems. Table 4 summarized the population based techniques in the literature that applied to solve university examination timetabling problem.

4.4 Hybrid Metaheuristics Techniques

Hybridization methods attracted researchers' interest in recent years with the reason to its superior performance in solving optimization problems (See Table 4). Combining a constructive element of different methods into one is the main idea of hybrid methods. The searching abilities of the hybrid method will be increased using this combination. Blum and Roli (2003) summarized that:

"*In summary, population-based methods are better in identifying promising areas in the search space, whereas trajectory methods are better in some way manage to combine the advantage of population-based methods with the strength of trajectory methods are often very successful*".

For instance, Turabieh and Abdullah (2011b) employed a hybrid method for examination timetabling problems that combined great deluge algorithm with electromagnetic-like algorithm. Other hybridization methods that are presented in solving university timetabling domain can be seen at (Fong et al., 2014; Bolaji et al., 2014; Jorge et al., 2014; Ferdoushi et al., 2014; Bolaji et al., 2015a; Caballero-Caballero et al., 2014; Abed and Tang, 2013; Abdullah and Alzaqebah, 2013; Tassopoulos and Beligiannis, 2012; Gunawan et al., 2012; Turabieh and Abdullah, 2011b; Nguyen et al., 2012; Tran and Ng, 2013; Alzaqebah and Abdullah, 2011c; Alinia Ahandani et al., 2012; Abdullah and Turabieh, 2008, 2012; Al-Betar and Khader, 2009; Turabieh and Abdullah, 2011a; Burke et al., 2010a, 2006a; Qu and Burke, 2009).

Initial implementation of MA was conducted by Burke et al. (1996) for examination timetabling problems. Their work incorporated a hill climbing optimizer within the mutation operator of GA. The crossover operator was eliminated from their method. Their MA system was evaluated using timetable instances which reflect real world examination timetables. It produced competitive outcomes when compared with the pure genetic algorithm (GA) system. Burke and Newall (1999) presented a multistage evolutionary algorithm for the same examination timetabling problem and a standard dataset released by Carter et al. (1996). The main motivation of their work is to minimize the timetable search space to the local optimal solutions.

The approach that generates the prominent results and made the major contribution on the instances of Carter datasets is known as hybrid approach and is proposed by Caramia et al. (2001). In this, to assign examination with the priority value, a greedy constructive heuristic was employed. The reduction of soft constraints violations was minimized by proposing user penalty minimize and for introducing new timeslots, penalty traders were used.

Abdullah et al. (2010) employed a hybridization between tabu search and memetic algorithm. The unperformed neighborhood structure is inserted in the tabu list for particular and specific iterations before it is available to be employed again. The tabu list is introduced in order to control the selection of the neighborhood structures. This approach is tested on Carter et al. (1996) datasets (eleven uncapacitated with cost) and able to obtain competitive outcomes than some of the popular outcomes in literature. At the same time Burke et al. (2010a) tackled U-UETP using a hybrid variable neighborhood search (VNS) that intelligently used GA to choose favorable neighborhoods subsets from a set of 23 such neighborhoods set. Largest degree heuristic can be generated with the VNS to feasible timetable to assign the examinations to a feasible period. For the purpose of producing technique, the authors used GA which could perform the generalization to a sequence of examination timetabling problems. This technique can be used to test Carter datasets and finest referral outcomes for two data sets can be made.

Electromagnetism-like mechanism combination was presented by Turabieh and Abdullah (2011b) with Great Deluge algorithm and force decay, based on attraction-repulsion idea of movement for search space solutions for examination timetabling problem. The study objective was to transfer to a high quality solution, some sample points with the addition of, avoidance of local minimal by using an evaluated force value. The hybrid technique was claimed to give an effective performance as compared to the other state-of-art techniques.

In order to solve the examination timetabling problems, another proposition was done by Turabieh and Abdullah (2011a) in the form of a hybrid fish swarm algorithm. The fish movement, in this algorithm is simulated during the searching process of food in the water. The categorization of search space can be done in three ways such as crowded, empty areas and not crowded. The determination of fish movement (represented the solution) is actually based on the Nelder-Mead simplex search algorithm. It could expand the solution's quality with utilization of steepest descent algorithm or a great deluge algorithm. On the group of problems related to benchmark examination timetabling can be tested by proposing the hybrid approach as compared to a group of state-of-the-art methods by general use of literature. Outcomes of the experiments reveal that there is a potential in hybrid approach to provide the potential outcomes for the problems of tests.

Alzaqebah and Abdullah (2011c) solved university examination timetabling problem by hybridized Artificial Bee Colony to SA that keep the balance of exploitation on the exploration processes. For the sake of onlooker bees, a disruptive selection strategy was introduced by the author in order to make a progress in the premature convergence and the population diversity along with the occasion of introducing the local search i.e., SA. In addition, to select the neighborhood structures, a self-adaptive strategy further added to expand the capability of the local intensification. In this method, the outcomes reveal that with the disruptive selection strategy, hybrid ABC outperforms the ABC logarithm on a single basis in the duration of testing the problems related to the examination timetabling.

The same authors proposed a hybrid self-adaptive bees algorithm (Abdullah and Alzaqebah, 2013) and a disruptive selection strategy (Alzaqebah and Abdullah, 2014) to make a progress in the population diversity and to prevent the premature convergence in the evolutionary process. Combination of a modified-bees algorithm with the late acceptance HCO assures the rapid descends in the optimum solution. Outcomes generated by the experiments by comparing the proposition modifications with bees algorithm also with one another reveals that all modifications outperform the bees algorithm. A comparison with the finest outcomes was made on datasets of two benchmark examination timetabling which also reveals that approach to be competitive perform well in all instances problems. On the other hand,

Alzaqebah and Abdullah, (2015) also hybridized BCO for UETP. They introduced three selection strategies (disruptive selection strategies, rank and tournament) for the follower bees to maintain population diversity. They introduced a self-adaptive mechanism to improve the neighborhood search. The proposed approach investigated as compared to the updated methodologies with respect to standard examination timetabling problems of two in count in literature, namely, uncapacitated and competition datasets. They demonstrated that the proposed algorithm provides one new competitive result on uncapacitated datasets and comparable outcomes on competition datasets.

Sabar et al. (2012a) proposed a variant of the Honey-Bee Mating Optimization (HBMO) algorithm to enhance the diversity of the solution search space, authors hybridized haploid crossover within the framework of HBMO. The proposed algorithm performance was tested on U-UETP. As per results, the author compared the performance of variant of HBMO algorithm with other techniques results in particular literatures. These other techniques showed that it is promising approach to solve much examination timetabling problem.

Gunawan et al. (2012) proposed a hybridized lagrangian relaxation method and SA technique for the examination timetabling problem, the initial solutions are obtained by a mathematical programming approach based on Lagrangian relaxation method and then enhanced by a SA algorithm. (Xu et al., 2014) investigates the robust graph coloring problem with application to a kind of examination timetabling by using the matrix semi-tensor product and presents a number of new outcomes and algorithm.

Abed and Tang (2013) described the combined use of genetic algorithm and Record-to- Record Travel (is another optimization method that has been introduced for local search). The authors hybridized the two algorithms to make the local search balance with a global search. They used Carter et al. (1996) datasets. The results showed that the proposed hybridization performed competitive when compared to the outcomes generated by genetic algorithm approach alone. A good result is achieved by minimizing the violation of the soft constraints.

Fong et al. (2014) combined artificial bee colony algorithm with a great deluge to solve examination timetabling problem. Hybridization is proposed to recompense the weaknesses of the ABC. Also, an assimilation policy is implemented in order to enhance the global exploration abilities for ABC algorithm. In addition, Nelder-Mead simplex search method is combined within the great deluge algorithm, the objective of which is to improve the exploitation abilities of the hybrid approach in fine-tuning the problem search region. The proposed approach is tested on Carter et al. (1996). The result shows the performance of the proposed approach is significantly competitive than basic ABC algorithm. Finally, the experimental outcomes are compared against state-of-art techniques, the comparison showed that the proposed method has competitive outcomes and in certain cases achieving some of the current competitive outcomes to those in the literature.

Bolaji et al. (2015a) presented a Hybrid ABC algorithm (HABC) to solve U-UETP. The proposed algorithm comes in two phases; hybridization is done in the first phase, a simple local-search approach as a local refinement process within the employed bee operator of the original ABC, whereas the replacement of the scout bee operator with the random consideration concept of harmony search algorithm applied to the second phase. The former is to improve the exploitation abilities of ABC. The Hybrid ABC algorithm is evaluated using Carter et al. (1996) dataset. The results showed that the Hybrid ABC is competitive than exiting ABC approaches and competes well with other approaches in the literature.

Fong C. W. et al. (2015) presented a new method based on the nature inspired ABC technique. The authors introduce a variant of the technique that utilizes a global-best model inspired from PSO to improve the global exploration ability that hybridizing with the Great Deluge technique in order to enhance the local exploitation ability. The proposed technique balanced between exploitation and exploration. On the other hand, a traditional local-search technique is hybridized within the Great Deluge technique including the aim of improving the performance of the overall hybrid technique. The authors investigated two diverse university timetabling benchmark to evaluate the performance of the proposed approach, such as, Carter's examination timetabling and Socha course timetabling benchmarks. The outcomes show that the proposed technique is able to produce high-quality solutions across both these dataset problems. Furthermore, the proposed technique generates good results on some datasets as compared with other techniques proposed in the previous studies.

Qu, R. et al. (2015) presented a hybrid technique based on estimation distribution methods. The authers raised the level of generality for search technique. The aim of the hyper-heuristic is to generate good quality solutions for a number of optimization problems. The authors demonstrated the generality through experimental results for different variants of exam timetabling problems. The hyper-heuristic introduces an automated constructive technique that searches for heuristic options from a given set of low level heuristics. The high level search technique based on a simple estimation distribution method has the capability of leading the search to select suitable. The probability distribution of low level heuristics at different stages of solution construction could be used to assess their effectiveness and probably support to enhance more intelligent hyper-heuristic search techniques.

Table 4 summarized the hybrid metaheuristics techniques in the literature that applied to solve the university examination timetabling problem.

4.5 Hyper-Heuristic Techniques

The term hyper-heuristic (Burke et al., 2003a) demonstrates the technique of operating abstraction of a high level as compared to most implementation of heuristics or metaheuristics. A hyper-heuristic may be considered as a heuristic selecting from a set of other heuristic. The main purpose of applying this method is to build a general optimization method that can solve different scheduling problems. Therefore, the major difference between hyper heuristics and other is that a hyper heuristic indirectly modifies solutions by employing the use of low-level heuristics while other heuristics modify the solutions directly. An overview can be provided by this section on the research which is conducted on several kinds of hyper-heuristics for examination timetabling as shown in Table 4. Selection perturbative, selection constructive also the production constructive hyper heuristics have been fairly well explored in previous research for examination timetabling whereas it seems to be lack of research in use of generation perturbative hyper heuristics in the current domain.

Selection constructive hyper heuristics

Yang and Petrovic (2005) studied a hybrid approach combining a great deluge algorithm and case-based hyper heuristic the to explain the examination timetabling problems. Great deluge (GD) algorithm expands a candidate explanation schedule shaped using a low level construction heuristic for example, saturation degree (SD), largest enrollment (LE), largest weighted degree (LWD), largest degree (LD) and largest color degree (LCD). Yang and Petrovic (2005) applied a case based hyper heuristic to select which structure heuristic to use to generate the initial solution. Examination timetabling problems was previously solved buy the case base stores and the construction heuristic used. When explaining a new examination timetabling problem, researchers used the hyper heuristic by employing a fuzzy similarity measure to match problem to problem in the case base in order to identify the construction heuristic to use it for generating an initial solution which a GD algorithm enhanced later. The case base was generated by applying the generated examination timetabling problems. The method shaped accurate and premium quality timetables for problems from the Carter dataset.

A selection constructive hyper heuristic use was investigated by Qu and Burke (2005a) for solving many problems in examination timetabling. The hyper heuristic engages variable neighborhood finds to study heuristic combinations space that consists of greater or equal to two graph coloring heuristics, namely, SD, LD, CD, LWD, random ordering and LE. Each heuristic is used in order to assign an exam to a minimum penalty period. The hyper heuristic approach provides the solution of many problems related to Carter benchmark was used.

Pillay (2014, 2012a, 2010, 2008) apply an evolutionary algorithm hyper heuristic in order to search a space of heuristic combinations of low level construction heuristics chosen from a set containing, saturation degree, largest degree, largest enrollment, largest weighted degree and highest cost heuristics. A good quality timetables was generated by applying the hyper-heuristic in order to produce both the benchmark set for the second international competition and the Carter set of benchmark problems for timetabling (McCollum et al., 2010). The effects of the representation, was also investigated, used for heuristic combinations on the performance of the EA hyper heuristic.

Burke et al. (2009) employed the greedy random adaptive search procedure (GRASP) to hybridize the use of two low level construction heuristics, namely, LWD and SD in choosing the next examination to schedule in the duration for the process of timetable construction. Proposed algorithm also used steepest descent to improve the candidate solution constructed. The author used Carter benchmarks.

Qu and Burke (2007) compared the performance of various hyper heuristics, each employing different approaches to investigate the heuristic space to solve the examination timetabling problem. These hyper heuristics search heuristics combinations space comprised of low-level construction heuristics. The combinations may be constructed by choosing heuristics from a set containing the LD, random ordering heuristics, LWD, SD, LCD, and also LE. The hyper heuristics were tested on eleven problems from the Carter dataset. The iterated local-search hyper heuristic to produce the competitive outcomes was found. The implementation of the hyper heuristic was enhanced by applying the searching of the solution space, applying iterative local search, at different intervals throughout timetable construction.

Sabar et al. (2012b) have applied a selection constructive hyper-heuristic for solving the problem. They combined four low-level heuristics in deciding order which examination to generate a potential schedule next. The last three heuristics in the combination were applied to deal with ties. The examination was allocated using the Roulette wheel. The hyper-heuristic arranged the set of benchmarks was examined for second competition for international timetabling and Carter benchmark set.

Generation constructive hyper heuristics

Burke and Newall (2004) proposed a heuristic method in order to solve the examination timetabling problem. A preliminary solution is formed by applying one heuristic of five. The heuristic assessed for each exam separately, then increased according to the presentation of the heuristics throughout the preliminary building. The heuristic value is increased when the examination was not been to be scheduled regarding a clash consequently. An exponential increment, namely *2n*, where *n* consider as the number of incremented times for the heuristic. This hyper heuristic was positively applied to solve the Carter dataset of problems. Asmuni et al. (2009, 2007a) combine low level graph heuristics, specifically, largest registration, fullness degree and largest degree using a fuzzy logic function. The fuzzy function chains two to three heuristics and the single value formed is applied to arrange examinations in order to be scheduled based on the difficulty. The hyper-heuristic was applied in order to solve and explain the Carter dataset.

Rahman et al. (2009) used same method as Burke and Newall (2004) and apply a heuristic change to correct heuristic values according to the successful achievement of. The fullness degree heuristics and LD are initially applied to assess the examination scheduling difficulty. In place of exams being scheduled some shuffling form of the sorted list of exams if firstly performed. The heuristic modifier was assessed on the Carter dataset. The SD heuristic was found to achieve competitive than LD.

Pillay and Banzhaf (2009) recommended that low level heuristics be joint hierarchically allowing them to be used simultaneously in its place of combining them linearly and using them sequentially. The use of logical and conditional operators has eased the hierarchical grouping and simultaneous application of low level construction heuristics selected from highest cost heuristics, LE, LWD, SD and LD. Four such groupings were formed and tested on the Carter dataset. These groupings produced good results compared to other hyper heuristics which was assessed on the same benchmark set of problems. Pillay (2012a) automates the process of generating the hierarchical heuristic combinations. In this his genetic programming is applied to improve these combinations comprised of logical and conditional operators and the low level heuristics.

Abdul Rahman et al. (2014) adapted a method to describe the trouble in scheduling an examination according to the weighted sum of one or more than one low-level heuristics and a heuristic alteration value calculated according to the trouble of scheduling the examination on the preceding iteration. The low-level construction heuristics used consider as the largest degree and saturation degree. The examinations are organized in descending order rendering to the difficulty and allocated accordingly to the least penalty slot. The method was created to do well on both the Carter and ITC 2007 benchmark sets.

Generation perturbative hyper-heuristics

Sabar et al. (2013) found that grammatical evolution hyper heuristic (GEHH) is carried out to produce perturbative low level heuristics to explain the problem of examination timetabling. The GE-HH produces one-use local search templates, collected of an acceptance standard, a neighborhood combinations and neighborhood structure, in order to solve an instance problem. The acceptance criterion agrees to accept or to reject the solution. The neighborhood structures are move operators which do small alarms to the neighborhood. Neighborhood combinations combine neighborhood structures, e.g. neighborhood union. A form of the hyper heuristic with adaptive memory was examined and the usage of this memory was created to improve the performance of the hyper heuristic. The adaptive memory stores diverse solutions and high quality and is improved regularly. This hyper heuristic was created to make good outcomes for both the ITC and the Carter 2007 datasets.

4 Critical Analysis of the Existing Techniques

Researchers in the recent years have developed a lot of the techniques and promising ideas for the examination timetabling problem. On several problems, they adopted a wide array of universal techniques and problem specific of countless diversities and characteristics. The implementation of graph coloring heuristics for examination timetabling problems was found to be the earliest techniques that produce solutions quickly to be very effective. Thus, the techniques are being used for creating feasible solutions. However, the low quality solutions are produced by them when compared with other techniques. They also exhibit some limitations to handle large problem instances.

Table 4 summarize several techniques that are applied to solve the U-UETP in the literature, classified by the type of algorithmic techniques. Metaheuristic techniques can be adopted in order to tackle the examination timetabling problems and they have yielded considerable successes (Qu et al., 2009b; Lewis, 2008). The metaheuristic is described as an iterative improvement process. In this technique, each metaheuristic comes with its own operators with a set of operators that are used to investigate the solution search. Metaheuristic approaches can be classified as;

- Local search-based techniques (e.g. Simulating Annealing (Thompson and Dowsland, 1998, 1996; Abramson, 1991; Johnson, 1990; Kirkpatrick et al., 1983), Great Deluge (Burke and Bykov, 2006; Burke et al., 2004), Tabu Search (Di Gaspero and Schaerf, 2003, 2001; White and Xie, 2001)).

- Population-based techniques (e.g. Ant Colony Optimization (Eley, 2007), Harmony Search Algorithm (Al- Betar and Khader, 2012; Al-Betar et al., 2010b), Artificial Bee Colony (Alzaqebah and Abdullah, 2014, 2011a, b, c; Bolaji et al., 2011a, b)).

Table 4: Summary of the literature work on related approaches and their characteristics for the uncapacitated datasets.

AUTHOR/S	ADVANTAGES	DISADVANTAGES
(THOMPSON AND DOWSLAND, 1996, 1998)	Able to escape from local optima.	• Many parameters need to be set and tuned.
(MERLOT ET AL., 2003)	Good in term of diversification and intensification and it is like a great deluge.	• Influenced by the generated random number. • Needs intensive computational requirements which need more time.
(BURKE AND NEWALL, 2003, 2004; BURKE ET AL., 2004; YANG AND PETROVIC, 2005; TURABIEH AND ABDULLAH, 2011B)	• Only it has two parameters. • The acceptance criteria used allow the worse solution for more exploitation. • Able to escape from local optima. • Good in intensification.	• Slow in iterative search process. • Not good in diversification.
(BURKE AND BYKOV, 2008)	• Only needs to tune one parameter. • The acceptance of the new solution is based on previous solutions obtained from the number of previous iterations. • Able to quickly explore the search space and can avoid from getting stuck into a local optima by accepting the worse solutions.	The performance is mainly related to the size of the list, different datasets have different size settings.
(DI GASPERO AND SCHAERF, 2001; WHITE AND XIE, 2001; DI GASPERO, 2002; WHITE ET AL., 2004; LOURENC¸O ET AL., 2001; BURKE ET AL., 2007; ABDULLAH ET AL., 2010)	• Fast in iterative search process. • Able to escape from local optima.	• Many parameters need to be set with tabu search. • Tabu list size affects the performance of the search process, thus, it needs to be set carefully.
(BURKE ET AL., 2006A; AYOB ET AL., 2006; BURKE ET AL., 2010C)	Intensification and diversification can be achieved from this algorithm through a local search and systematically change the neighborhood structure.	It deals with large number of neighborhood structures, thus, the algorithm takes more time.
(CÔTÉ ET AL., 2005; ROSS ET AL., 2004; BURKE ET AL., 2006B; PILLAY AND BANZHAF, 2010)	Good in exploring the search space and diversification.	• Slow processing. • The parameters need to be set carefully. • Not good in the intensification.
(ERSOY ET AL., 2007; ABDULLAH ET AL., 2010)	The exploitation is improved as compared with exploration process by employing a local search algorithm.	• In term of speed it is faster than genetic algorithm. Number of parameters depends on the genetic operators employed (some memetic algorithms involve a crossover operator, and some are not).
(ELEY, 2007)	• Good in discovering new solutions. • Able to avoid the premature convergence.	• Efficiency of the algorithm depends on the ability of the local search employed. • In term of speed it is reported as a slow algorithm. Involves a number of parameters.
(TURABIEH AND ABDULLAH, 2011A)	The exploitation is improved as compared with exploration process by employing a local search algorithm.	• Not effective as an improvement algorithm. The approach depends on the efficiency of the local search which is used based on the total force value.
(SABAR ET AL., 2009A, 2012A)	Ability to explore and exploit the search space.	The number of parameters that need to be set earlier.
(TURABIEH AND ABDULLAH, 2011A)	Good in exploration and diversification.	• Involved a number of parameters. Not good in intensification.

The population-based techniques are capable of exploring the regions of several multiple search space within a single duration of time. These techniques somehow, are poorer often to find a specific local optimal solution in each region of converging search space (Fesanghary et al., 2009). The ordinary Search-based techniques were able to fine-tune the regions of the converged search space and a local optimal solution can be found precisely. However, without a wider scan task of whole, in a search space the techniques could go through a trajectory. Therefore, hybridizing a local search within a population-based technique has also been employed for UETP such as the hybrid evolutionary algorithm with the variable neighborhood search (Abdullah et al., 2007c) and a hybridized evolutionary approach with the non-linear great deluges (Landa-Silva and Obit, 2009).

To cope with the university timetabling problems and its nature, most metaheuristics approaches have been adopted (Qu et al., 2009b; Lewis, 2008). The limitation in this technique is in terms of the domain specific knowledge and the setting of parameters that lies in the problem, which must be embedded into them (Qu et al., 2009b; Lewis, 2008). Each technique may perform well against others with respect to its particular problem (Qu et al., 2009b). The domain can be provided with more general techniques by hyper heuristics techniques that could be handled by the several formulations in timetabling problems. In this, the weaknesses of metaheuristic may be alleviated. The issue lies in the process, and thus, in order to obtain quality solution, this technique requires further investigation.

The hybrid technique is a technique on which many investigations that produce the quality solutions in the domain of timetabling are based. The hybridized local search technique is assumed to be a most common hybridized technique, it help to maintain the balance in between exploration and local exploitation by combined between good population based technique and good local based technique. In other words, it can be summarized that the local search-based techniques are competitive in navigating the promising regions of solution search space while the population-based techniques are better in identifying the promising regions of the solution search space. Therefore, the hybrid technique is often very good as it combines the advantage of both techniques for the best solution searching (Al-Betar et al., 2012c).

This paper is concerned with the U-UETP. A wide variety of approximation methods have been investigated. These methods include (i) heuristics/Graph coloring techniques (Abdul Rahman et al., 2014; Sabar et al., 2012b; Hussin et al., 2011; Kahar and Kendall, 2010), (ii) the local search-based techniques (Acan and U¨ nveren, 2014; Obit et al., 2011; Turabieh and Abdullah, 2011b; Alinia Ahandani et al., 2012; Duong and Lam, 2004), (iii) the population-based techniques (Jha, 2014; Innet, 2013; Pillay and Banzhaf, 2010; Thepphakorn et al., 2014; Lewis, 2008; Alzaqebah and Abdullah, 2014; Abdullah and Alzaqebah, 2013), (iv) the hybrid metaheuristic techniques (Fong et al., 2014; Bolaji et al., 2014; Jorge et al., 2014; Ferdoushi et al., 2014; Bolaji et al., 2015a; Caballero-Caballero et al., 2014; Abed and Tang, 2013; Abdullah and Alzaqebah, 2013; Tassopoulos and Beligiannis, 2012; Gunawan et al., 2012; Turabieh and Abdullah, 2011b; Nguyen et al., 2012; Tran and Ng, 2013) and (v) the hyper-heuristic techniques (Pillay, 2014, 2012a, 2010, 2008; Qu and Burke, 2009). The best solutions can be obtained by the hybrid metaheuristic Techniques. It may be found especially from those techniques which are hybridized to incorporate a local search-based Technique within a population-based technique.

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