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Design and Implementation of Doctor Scheduling System Using Graph Coloring and Backtracking Approach

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***Abstract*—** The availability of doctors is a major problem that people are facing especially in the rural areas. On the other hand, there are some areas which have large number of doctors than actually required. Because of this uneven distribution of doctors, people in the remote areas remain deprived of medical facilities and are living an unhealthy lifestyle. This paper describes the optimization of schedule of doctors using graph coloring and backtracking approach so that they can be evenly distributed across various locations and the people who are currently not getting proper medical facilities will be able to get treatments on time. This technique serves two purposes, namely, resource optimization and cost optimization. An optimized schedule of doctors will be provided. Only the required number of doctors will be present at a particular location. The remaining doctors will be sent to some other locations. If implemented on a large scale such as in government schemes, this can be a great contribution to the society.

***Keywords*—** Graph coloring, resource optimization, cost optimization

I. INTRODUCTION

Graph coloring is a technique used in graph theory which consists of coloring the components (vertices and edges) of a graph with minimum number of colors. It is a special case of graph labeling. In graph labeling, integer numbers are assigned to the components of the graph whereas colors are assigned in case of graph coloring. The coloring is done in such a manner that no two adjacent vertices or edges are of the same color. There is no exact solution of graph coloring problem and that is why it is known as NP-hard problem. Graph coloring is used in many real world applications of computer science.

Chromatic Number: The minimum number of colors required to color a graph is known as the chromatic number. It is denoted by X(G).

Vertex Coloring: Assignment of colors to the vertices of a graph such that no two adjacent vertices get the same color is known as Vertex Coloring. In other words, no two vertices connected with the same edge should be assigned the same color.

Edge Coloring: Assignment of colors to the edges of the graph such that no two edges that are incident get the same color is called Edge Coloring.

Backtracking: Backtracking is an algorithm used to find solutions to constraint satisfaction problems. [1] It incrementally builds candidates to the solutions, and backtracks when it finds out that the candidate cannot possibly be completed to a valid solution. Backtracking can be used only for problems with a concept of "partial candidate solution" and a relatively quick test of whether it can possibly be completed to a valid solution. When it is applicable, however, backtracking is often much faster than brute force enumeration of all complete candidates, since it can eliminate a large number of candidates with a single test. Backtracking is used to solve constraint satisfaction problems, such as crosswords, verbal arithmetic, Sudoku, and many other puzzles. It is often the most convenient technique for parsing and other combinatorial optimization problems. A search tree is traversed recursively by the backtracking algorithm from the root down, in depth-first order. At each node, the algorithm checks whether the node can be completed to a valid solution. If it cannot, the whole sub-tree rooted at that node is skipped (pruned). Otherwise, the algorithm checks whether the node itself is a valid solution, and if so reports it to the user; and recursively enumerates all sub-trees of the node. In graph coloring, backtracking is implemented by reassigning colors to the already colored vertices dynamically to minimize the number of colors. There are three phases of backtracking algorithm. [2] The first one is the forward phase in which the consecutive variable in the ordering is selected. In the next phase, a consistent value is assigned to the current partial solution if it exists. Finally in the backward phase, when there is no consistent value for the current variable, the focus is returned to the previous current variable. A modified algorithm of the conventional backtracking algorithm is called dynamic backtracking. [3] The conventional backtracking algorithm sometimes back jumps to the wrong nodes. While doing so, some of the efforts made to reach the present node go in vain. Dynamic backtracking algorithm at least can retain the values of the nodes that are back jumped, moving them at the end of the partial solution for replacing their values without modifying the values of other variables representing other nodes. Another modification of the conventional backtracking algorithm is back jumping in which the algorithm jumps to the highest node which had a conflict with had a conflict with the current variable instead of going back to the parent node. [4] This is useful in reducing the amount of thrashing. The cost involved in maintaining the consistency checks is also small. An advanced backtracking algorithm called backtracking survey propagation algorithm has a new backtracking step in which a variable containing a value can be released and the same can be used to assign values in future steps. [5]. In this paper, we propose an optimized schedule of doctors across various locations with the help of a backtracking based graph coloring algorithm. At present because of the uneven distribution of doctors across locations, some areas do not have an optimum number of doctors available while some areas have more doctors than actually required. This is not an efficient utilization of resources and cost. The idea is to cover maximum areas with minimum number of doctors which will help the people especially in remote areas to get medical facilities from which they are deprived till now. An added advantage of this approach is that the algorithm will provide the schedule of doctors in a fraction of second as compared to the time taken in manual scheduling.

This paper is structured as follows: Section 2 provides the related work. Section 3 contains the methodology used. Section 4 shows experimental results and analysis. Section 5 concludes the paper and suggests future enhancements.

II. RELATED WORK

A lot of research has been done on graph coloring algorithm as well as its applications. Some of them are summarized as follows:

J.T. Camino, S. Mourgues, C. Artigues, L. Houssin (2014) [6] observed that there is a need to optimize the satellite resources in the most efficient manner. This could be done when the satellite systems designs are made better. In case of multi beam satellites, optimal use of plurality of beams was made in terms of reuse of frequency, layout quality and power allocation. Beam layout optimization is a crucial and complex task as it affects the cost and performance of the resulting system. The key data is the repartition of the traffic over the zone to be covered which is mostly non uniform in case of broadband systems. The regular scheme has a very strong advantage that it is compatible with single feed per beam antenna constraint of minimum angular distance for all couples of beams coming from same reflector. A randomized multi start heuristic was presented to build a non uniform layout. The antenna constraint was dealt with by a graph coloring procedure via local search and simulated annealing. An alternate option was provided for building non-uniform layouts with a dynamic consideration of the single feed per beam antenna constraints; the good RF performances have made an interesting solution for multi beam systems. This was only the first step that included the allocation of power and frequency to the beams. A tool was provided to build irregular layouts algorithmically which guarantees feasibility for its implementation with SFB antennas.

B. Hussin, A.S.H. Basari, A. S. Shibghatullah, S. A. Asmai (2011) [7] provided an approach to schedule the exam time tables for centre for foundation studies and extension education (FOSEE), Multimedia University, Malaysia. Timetabling as a whole covers large number of problems which have their unique characteristics. In education sector, there are 3 most common academic time table problems viz. school, university and exam time tables. Exam time tabling is a complex task and it is very difficult to do it manually. The problem included dual academic calendar, resource limitations and increase in the number of students. The solution which was provided was a heuristic approach including graph coloring, cluster and sequential heuristic. A time table is considered of a good quality if the soft constraints taken under consideration are minimized. Clustering heuristic decomposed the subject based on the characteristic and this technique of filtration became very important when conflict matrix was applied to detect clashing subject. It was easier to recheck the clashing of the subject based on cluster color with the help of conflict matrix table. A feasible approach for exam time table in FOSEE, MMU was provided using new technique which was made by combining clustering and graph coloring heuristics. It was found that graph coloring heuristic is suitable for the problems that focus on hard constraints but not for soft constraints. It was suggested that this solution can be applied as an automated system whose output would be more consistent and the method can be applied to a problem of any size.

N. Barnier, P. Brisset [8] provided a design of a new route network that optimized the criteria of operational costs while satisfying Air Traffic Control constraints. Their idea was to consider only direct routes and vertically separate the intersecting ones. This problem was solved using constraint programming after large cliques were found using greedy algorithm. The cliques were used to post global constraints and provided guidance to the search strategy. The size of the largest clique was taken as the lower bound of minimum number of flight levels. Then, a variable ordering based on the set of cliques found in this step was used in a branch and bound to search for the minimum number of flight levels. In this process, when the instantiation of a flow to a new level occurred, the symmetry between the equivalent flight levels was broken. When implemented using Functional Constraint Library, except the largest instance, for all other instances, optimality was achieved. These optimal solutions suggested that traffic could fit within the upper airspace. This traffic would be separated from those flights which could fly at lower flight levels and differently handled by the ATC. This method only aimed at providing the feasibility for redesigning of ATC. In actual practice, some additional constraints need to be taken into account so that more efficient methods can be used to find larger cliques so that more flexibility can be provided by designing the criteria to select the cliques dynamically.

M. Zais, M. Laguna [9] addressed an external factor of personnel inventory behavior, deployment. They showed that the deployment scheduling and unit assignment problem can be represented as an interval graph. They structured this problem efficiently and solved it by doing some modifications to the existing coloring methods. This problem sought to improve multiple objectives. First-fit and FFL were the primary algorithms which were presented with a swapping heuristic which sought to improve their solutions against the objective which minimized locations per unit. BOG: Dwell conflicted with an objective to reduce units because increasing in supply for unit sourcing could be used to increase average dwell time. The solutions provided by the algorithms were reasonably close to a goal of one location per unit. The FFL swap algorithm is the most efficient method to target location objective whereas first-fit algorithm provides an optimal solution against the unit supply objective. This research demonstrates how these methods can be used to reduce the size of its force structure requirements and reduce costs.

S. Ahmed [10] presented the importance of graph coloring ideas in various computer science application areas. He addressed the problem of guarding an art gallery with camera. Keeping an eye on the events happening during the day is easy by the security staff but it is difficult to do the same during night. This is done with the help of video cameras which are hung from the ceiling and rotate about a vertical axis. The images captured are sent to the screens in the office. Using graph coloring, the whole area of the gallery was covered by using minimum number of cameras. The main advantage of this is a reduction in the overall cost of the security system. The gallery was modeled as a polynomial region in the plane, precisely a simple polygon. A camera position represented a point in the polygon. The camera saw those points in the polygon which could be connected with an open segment lying in the interior of the polygon. It was found that for a simple polygon having n vertices, n/3 cameras are necessary and sufficient for every point to be visible by at least on camera.

III. METHODOLOGY

The requirements of doctors at a given point of time at different locations were taken. Data sets of requirements were of size 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 150, 175, 200 and 250. The requirements of a data set were compared with each other. If the time slots of two requirements overlapped, they were connected with an edge. In simple words, if there were two overlapping requirements, the same doctor could not be assigned duties at those locations at the same time. The graphs of these data sets were represented in the DIMACS format in a file with .col extension. This file contained the number of requirements, number of edges and the adjacency list of the graph. This file was given as an input to a backtracking based graph coloring algorithm. It provided an optimized schedule of doctors which was the minimum number of doctors required and the time of execution of the algorithm. Figure 1 shows the flowchart of the entire process.

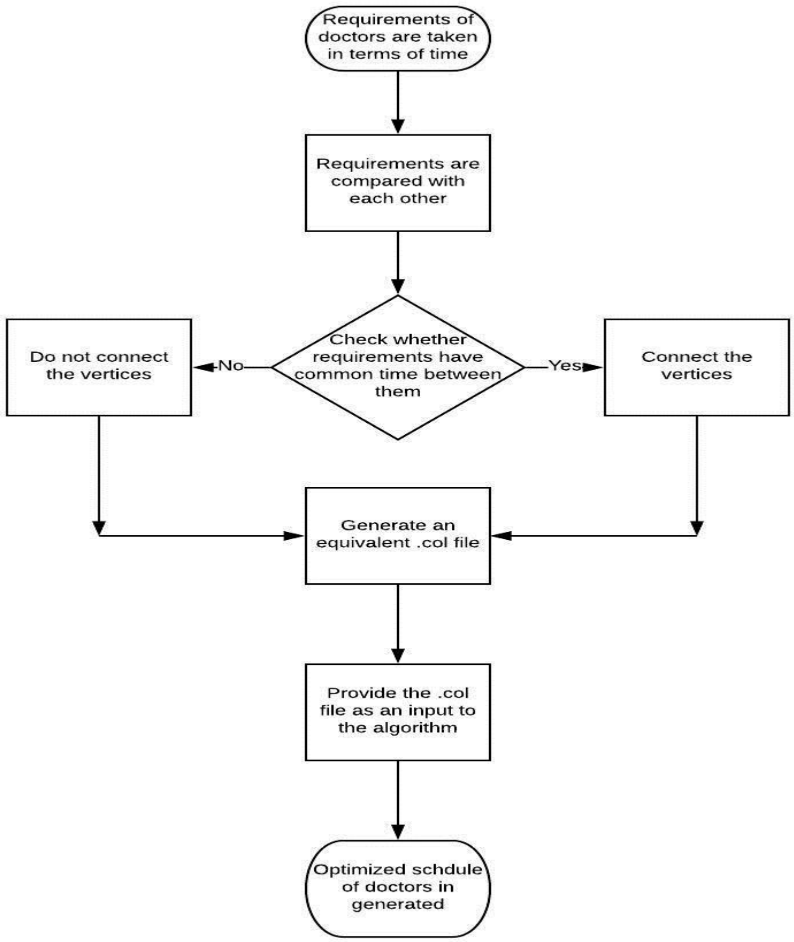

Figure 1: Optimizing Schedule of Doctors

IV. RESULTS AND DISCUSSION

The algorithm provided an optimized schedule of doctors. It greatly reduced the number of doctors required at a particular location. It provided the result in milliseconds as compared to the time taken in creating manual schedule of doctors. Table 1 shows comparative study between actual and optimized requirements along with the time taken by the algorithm to generate the schedule. Figure 2 shows the graphical representations showing comparative results of actual and optimized requirements. The results show that there is a significant difference between the actual and optimized requirements of doctors. Based on the sample size, on an average 55 % reduction in the number of doctors can be done if scheduling is done using graph coloring. These doctors can be sent to remote areas where there is a scarcity of doctors so that more patients can avail the medical facilities. Moreover, the time taken by the algorithm to provide the schedule is in millisecond which significantly differs when scheduling is done manually.

Table 1: Experimental Results

Data Set	Actual Requirements	Optimized Requirements	Execution Time
1	10	7	312.00 ms
2	20	12	361.00 ms
3	30	18	431.00 ms
4	40	18	459.00 ms
5	50	18	463.00 ms
6	60	26	482.00 ms
7	70	26	583.00 ms
8	80	41	548.00 ms
9	90	35	598.00 ms
10	100	42	594.00 ms
11	120	47	610.00 ms
12	150	51	672.00 ms
13	175	73	719.00 ms
14	200	70	828.00 ms
15	250	87	860.00 ms

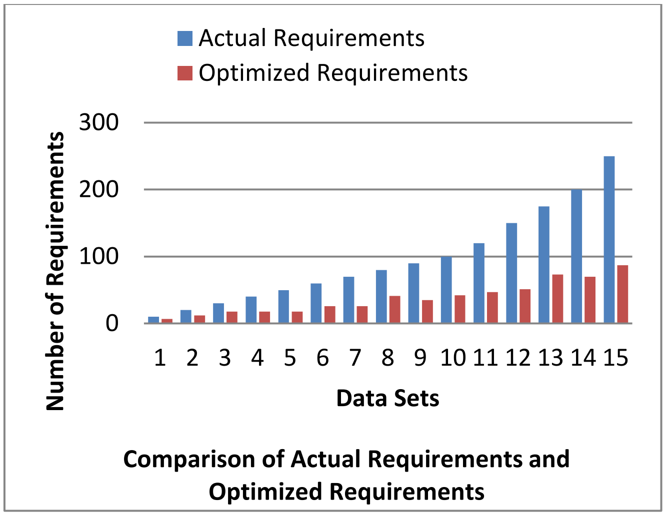

Figure 2: Actual Requirements vs. Optimized Requirements (Individual Results)

V. CONCLUSION AND FUTURE SCOPE

Scheduling of doctors can be done with the help of graph coloring algorithm. Also, the time taken by the algorithm to generate the schedule of doctors is negligible as compared to the manual process of scheduling. Presently, there is an uneven distribution of doctors across various locations. At some places, there are more doctors available than actually required whereas at some places there are hardly any medical facilities. When it comes to villages and remote areas, people are left unaided. Graph coloring algorithm greatly reduces the number of doctors required and thus helps in optimization of resources. The remaining doctors can be sent to the areas where there is a crunch of doctors. In remote areas, people are not able to get treatments on time. As a result, they become helpless and live an unhealthy lifestyle. If implemented on a large scale, this can be a great contribution to the society and can provide better facilities in the field of healthcare.

The requirements taken in the data sets were taken keeping in view a very small healthcare body such as a hospital or a health camp. This approach can be implemented on a large scale such as a city or a state. In those scenarios, constraints such as lunch time, travelling time from one location to another, weekends, number of shifts of doctors need to be kept in mind.

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