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SOLVE THE ELDERLY ALLOCATION PROBLEM IN NURSING HOMES BASED ON GREEDY AND BACKTRACKING ALGORITHM

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Abstract—
The problem of assigning elderly roommates in nursing homes has been a pervasive challenge in the society. This paper presents a new approach to room allocation in nursing homes after reviewing papers addressing class schedule problems using greedy and genetic fusion algorithms. This method aims to address the shortcomings of traditional room assignment techniques by incorporating the individual circumstances of older adults. Utilizing the framework of a greedy algorithm, the proposed method involves a preliminary step in which a questionnaire is administered to elderly residents. The survey took into account factors such as wake-up time, sleep schedule, physical health, personality traits and financial status. Importantly, older adults can autonomously assign weights to each option based on their individual circumstances. After obtaining the responses to the questionnaire, the degree of matching among elderly residents was calculated. Those with a high degree of matching will be assigned to a shared room. Notably, the approach not only prioritizes individual preferences, but also promotes harmonious interactions among residents. In order to gain a comprehensive understanding of the effectiveness of the method, the time complexity is discussed. This proves that the proposed method outperforms traditional methods in terms of performance. In contrast to traditional room allocation methods, this approach places great emphasis on considering the unique circumstances of elderly residents. This thoughtful approach is expected to facilitate improved interaction and cohesion among residents while optimizing the time complexity of the allocation process.

Keywords: Nursing Homes Allocation Problem; Backtracking Algorithm; Greedy Algorithm; Time complexity;

I. INTRODUCTION

The increasing global aging population presents a pressing challenge for societies worldwide, necessitating innovative solutions to ensure the well-being and care of senior citizens. One pivotal aspect of addressing this challenge is the allocation of rooms within nursing homes or senior care centres. As individuals enter their golden years, their living arrangements become integral to their quality of life, social interactions, and overall satisfaction. Consequently, devising an effective room allocation strategy within such facilities becomes paramount [1].
The complexities surrounding room allocation in nursing homes stem from a confluence of factors. With young generations often grappling with busy lives and limited time for

caregiving, many elderly individuals seek refuge in specialized care centres to receive the attention and assistance they require. However, the rising costs associated with nursing home care, coupled with a preference among the elderly to coexist with peers, have created a dynamic landscape that demands thoughtful consideration.

In recent years, computational algorithms have emerged as a valuable tool to tackle intricate challenges in various domains, and room allocation in nursing homes is no exception [2]. Among these algorithms, the greedy algorithm stands out for its ability to provide pragmatic solutions through a sequential decision-making process. By iteratively selecting the most favourable option at each step, the greedy algorithm offers a promising approach to address the complexities of room allocation within senior care facilities [3].

Before writing this paper, it was inspired by the greedy algorithm in the main reference book, so this paper will use the greedy algorithm to solve the room allocation problem. And while using the greedy algorithm, it will also add the idea of backtracking, because the fusion method often performs better than the single algorithm to solve the problem.

There are several parts in this article. The first part is the algorithm description. Secondly, it briefly describe the greedy algorithm and summarize the content of the main reference paper using the Greedy and Genetic Fusion Algorithm for course timetabling problem. Next, it is the proposed solution part, it will describe the main process of the elderly in nursing homes allocation using mainly greedy algorithm and analyse its time complexity. The final part is the conclusion, it will summarize again and briefly describe the improvement methods that can continue to improve the allocation methods in the later period.

II. ALGORITHM DESCRIPTION

A. Description of Greedy Algorithm

Greedy algorithm can be simply described as: sort a set of data, find the minimum value, process it, find the minimum value, and process it again. That is to say, the greedy algorithm is an algorithm that takes the best or optimal choice in the current state in each step of the selection, and hopes to get the best or optimal result[4]. Greedy strategy refers to a problem-solving method that starts from the initial state of the problem and obtains the optimal value (or better solution) through several greedy choices. The greedy strategy always makes the best choice in the current view, that is to say, the greedy strategy is not considered from the whole, the choice it makes is only a partial optimal solution in a certain sense. The biggest feature of the greedy algorithm is that it is fast, usually linear quadratic, and does not require much additional memory [5].

B. Summary of the Main Reference

1)Description of the TCP and the Introduction of the main reference: In the main reference, the author mentioned that Course Timetabling Problem (CTP) is a nondeterministic polynomial time-complete problem which is hard to be solved[8]. And the author proposed a Greedy and Genetic Fusion Algorithm (GGFA) to solve Course Timetabling Problem efficiently, which can obtain the local optimal solution by using Greedy Algorithm and provide a high-quality initial population for Genetic Algorithm. And the results proved that Greedy and Genetic Fusion Algorithm proposed in the paper has the stronger optimal ability [1] .

The object of the CTP study can be treated as a five-tuple:
Resource=<C, P, R, T, S>

Table1. Resources of CTP

Symbols	Description
C	Class Collection $\{c_1, c_2, c_3, \dots, c_n\}$
P	Teacher Collection $\{p_1, p_2, p_3, \dots, p_n\}$
R	Classroom Collection $\{r_1, r_2, r_3, \dots, r_n\}$
T	Time-slot Collection $\{t_1, t_2, t_3, \dots, t_n\}$
S	Subject Collection $\{s_1, s_2, s_3, \dots, s_n\}$

The main purpose is to find the corresponding space-time slice (T, R) for a given set (C, P, S)[10].

2) Greedy and Genetic Fusion Algorithm: Steps of solving examination timetabling problem are shown in Fig. 1.

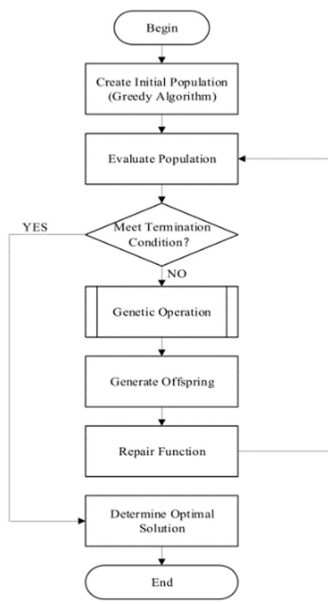

Fig. 1. Flow chart of GGFA

3) A new encoding method: This paper puts forward a new encoding method, Tuple Structure Encoding in this paper. This method regards a teaching plan as a tuple. The coding scheme is shown in Fig. 2.

Gene 1	Subject	Teacher	Class	Day of Week	Section of Day
Gene 2	Subject	Teacher	Class	Day of Week	Section of Day
Gene 3	Subject	Teacher	Class	Day of Week	Section of Day
			...		
Gene N	Subject	Teacher	Class	Day of Week	Section of Day

Fig. 2. Chromosome coding scheme

4) Initial Population (Greedy algorithm): The main function of the greedy algorithm is to initialize population. The Standard Genetic Algorithm (SGA) adopts the random method to produce the initial population, which is prone to precocity [8]. To optimize initial population, the authors use Greedy Algorithm to generate the initial population as evenly and reasonably as possible in the genetic space. In this way, they can ensure that Genetic Algorithm can get the global optimal scheduling scheme and avoid the precocity[9].

5) Evaluation function: The evaluation function is an indicator of the chromosome in the population. In each generation, the fitness of the whole population is evaluated, multiple individuals are stochastically selected from the current population based on their (fitness), modified (mutated or recombined) to form a new population, which becomes current in the next iteration of the algorithm. The Evaluation Function is used as follows:

$$E=\sum_{j=1}^{n_{class}}(E1_j + E2_j + E3_j) \quad (1)$$

Evaluation function evaluates the fitness of the individuals through three aspects:

E1: Fitness of Gene.

$$E1=\sum_{i=1}^{L} W_i \times D(W_i) \quad (2)$$

E2: Evenness of Time.

$$E2=\sqrt{\frac{1}{n_{day}} \times \sum_{i=1}^{n_{day}}(N_i - \bar{N})^2 + 1} \quad (3)$$

E3: Evenness of Courses.

$$E3=\sum_{i=1}^{n_{subject}} \sqrt{\frac{1}{n_{day}} \times \sum_{i=1}^{n_{day}}(M_i - \bar{M})^2 + 1} \quad (4)$$

Table2. Symbol description.

W_i	The weight of each course.
$D(W_i)$	Calculates the score of each course in a arranged timetable.
N_i	The number of total courses in some day.
$\bar{N}$	The average number of the courses in a week.
M_i	The number of total courses in the same subject in a day.
$\bar{M}$	The average number of the courses in the same subject in a week.

6) Genetic Process and Conclusion: First, the authors choose an individual (chromosome) in the current population using Roulette Wheel Selection according to its fitness. Then, they select an operation (Crossover Operation, Mutation Operation, and Reserve Operation.) randomly based on the probabilities of each operation[7]. These simulate the process of biological evolution. There are two termination conditions of Genetic Algorithm: one is the population fitness is stable for several generations, the other is setting the maximum of iterations. Finally, the author got a high fitness value and reduced the course conflict rate. In addition, the author thinks it is certain that combining different algorithms and providing a good initial value for heuristic algorithm can obtain a better effect.

III. PROPOSED SOLUTION

Having engaged with the contents of the referenced article, this paper endeavored to synergize a hybrid approach encompassing the principles of a greedy algorithm and backtracking. This fusion was directed towards addressing the intricate challenge of allocating rooms within nursing homes. Concurrently, it sought to formulate a refined objective function, a pivotal aspect in this endeavor, necessitating a holistic assessment of each elderly individual's distinctive attributes.

In light of meticulous investigation and comprehensive analysis, a compendium of five salient attributes was meticulously discerned. These attributes – encompassing sleep patterns, waking routines, personality traits, and financial considerations – were deemed to be quintessential in encapsulating the persona of each elderly resident. A structured questionnaire was meticulously fashioned, incorporating these quintessential factors into its fabric. The culmination of this meticulous effort is eloquently captured in the tabulated representation as presented in Table 3.

Table 3. The elderly personality questionnaire.

Questions	Options	
wake up time	before 7 o'clock	after 7 o'clock
sleep time	before 23 o'clock	after 23 o'clock
physical health	can take care of themselves	can't take care of themselves
personality	extroverted	introverted
household savings	below $500,000	over $500,000

A: Time Complexity of Traditional Greedy Algorithm and Backtracking

There are some researches on room allocation algorithms mainly backtracking and greedy algorithm. When the backtracking method is used for room allocation, the number of the elderly is divided into m groups (m is the room capacity), each group has n people, and the time complexity is O(n(m)!) [3]. For greedy algorithm, assuming that the room capacity is m, n is the ratio of the total number of the elderly to m. Each time one target older person is selected to calculate the matching degree with the remaining older people, the older people are re-sorted according to the matching degree, and then the top of the remaining older people (m -1) is the people that will live with the target person. The time complexity is $O(mn^2)$ [6].

B: Scoring System for Room Allocation

In this article, using the basic concept of the greedy algorithm, and drawing on the idea of backtracking method of stratification, the total number of the older people is divided into i groups (i is the room capacity), and the number of people in each group is j, which is the matrix of i × j. Then, greatly reduce the time required to calculate the matching degree. Arrange dormitories for the older people according to their 5 attributes (wake up time, sleep time, physical health, personality, household savings). The goal is to have similar attributes among the elderly in the same room, that is, the standard deviation is as small as possible, and the standard deviation is calculated layer by layer. Before an old man lives in a room, calculate the standard deviation of the people's property of the nursing homes after the people joins the room, so as to achieve that the people's stay is smaller than the standard deviation of other old people on the same floor.

In order to understand the habits of the seniors, the old people need to fill out a questionnaire before living in a nursing home. According to table2, the value of the second column is “1” and the value of the third column is “-1”. And the old people are ranked according to the influence of these indicators on themselves. The scores (weights) corresponding to the 5 indicators can be selected from 1 point, 2 points, 3 points, 4 points and 5 points. For accuracy, if the first indicator chooses 1 point, then the second indicator can only choose 2 points, 3 points, 4 points, and so on. The final score is the value in the second or third column multiplied by the corresponding score, so there are 10 possible values for each indicator from -5 to +5.

C: Symbol Description and Objective Function

Next, I will give the objective function of using greedy calculation to distribute rooms. In order to facilitate understanding, I will first give some symbol descriptions in Table 4.

Table 4. Symbol description.

f(x,y)	Objective function
C_{sum}	Room capacity
S[x][y]	The survey score, x=C_{sum}, y=5
avg	Average of each survey
P[i][j]	People array, i=C_{sum}, if T_{sum} is odd number j= (T_{sum}/C_{sum})+1 , if T_{sum} is even number j= (T_{sum}/C_{sum})
T_{sum}	Total number of the old people

The following is the objective function of this report.

$$f(x, y) = \min \sum_{y=1}^{4} \sqrt{\frac{\sum_{i=1}^{n} (S[x_i][y] - \text{av}\ )^2}{n}} \qquad (5)$$

$$1 \leqslant n \leqslant C_{sum}, \text{ n takes an integer} \qquad (6)$$

RMSD_y = √((∑_(i=1)^n ((S[x_i][y] - avg)^2) / n))

∑_(y=1)^4 RMSD_y = RMSD_1 + RMSD_2 + RMSD_3 + RMSD_4 (7)

f(x) = min (RMSD_1 + RMSD_2 + RMSD_3 + RMSD_4)

$$avg = \frac{\sum_{i=1}^{n} Y[x_i][y]}{n}, \text{ y=1,2,3,4,5} \qquad (8)$$

D: Steps for Using the Greedy Algorithm and Backtracking to Allocate Dormitories

The steps for using the greedy algorithm to allocate rooms are as follows:

(1. Selection of Resource Set (Room Selection):

(2. Initial Occupant Selection from the First Layer of the Demand Set (S[i][j]): Begin by selecting an individual from the initial layer of the demand set S[i][j] to occupy the designated room. Gather survey information about the chosen individual, identified as P[x][y], and update their check-in status to "checked in."

(3. Successive Occupant Selection from Subsequent Layers: Progressively, consider individuals from the second layer who have not yet taken up residence. Simultaneously, retrieve the corresponding survey data from the survey set P[x][y]. Employing the objective function f(x, y), calculate the sum of standard deviations for the five attributes of these individuals. Identify the individual linked to the minimum sum of standard deviations f(x, y). This person, situated in the second layer, forms the optimal match for the initial occupant selected in the prior step. Subsequently, admit this individual to the nursing homes by adjusting their status to "admitted."

(4. Extension to Additional Layers: This process continues iteratively for subsequent layers. On each iteration, prioritize minimizing the objective function value following the inclusion of occupants from the current layer, rather than striving for an optimal solution encompassing the entire objective function. Upon completion of the cycle through the Csum line, the remaining occupants within the Csum group are those that best align with the assigned room.

Accompanying Figure 4 provides a visual depiction of the comprehensive procedure for intelligent room allocation.

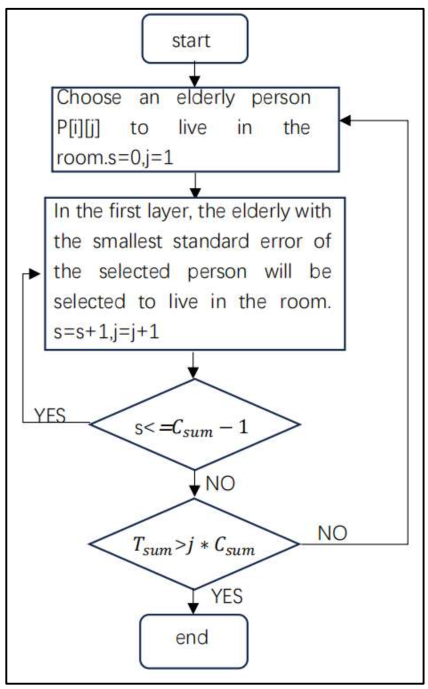

Fig.4. Flow chart of smart room allocation

E: Time Complexity

From the above analysis steps, we can see that the old people are divided into i groups (i is the room capacity), each group of people is j, and they are stored in the matrix P[i][j]. Because each search only needs to be performed on the same layer by the elderly, the time complexity of each search is O(j). Since the search depth is i, the total time complexity is O(i* j). Compared with the backtracking method of similar problems (O(n(m)!)) and the greedy algorithm (O(mn^2)), the efficiency has improved a lot.

IV. CONCLUSION

Nursing homes are a relatively special group of people in society. The algorithm described above was devised as a solution to the room allocation problem. It combines the principles of the greedy algorithm with insights from the backtracking method, which were inspired by a study on the CTP (Combinatorial Test Problems). A notable distinction between this method and traditional room allocation approaches lies in the inclusion of a pre-room assignment questionnaire survey for elderly individuals. This survey takes into account their individual personalities, with a focus on minimizing standard deviations, indicating similarity between individuals.

A significant departure from the traditional greedy algorithm is the integration of the backtracking concept. The approach involves partitioning the total number of individuals into "i" groups, where "i" represents the room's capacity. Each group comprises "j" individuals, forming an "i × j" matrix. This division substantially reduces the time required for calculating compatibility scores.

To enhance the coherence among aging roommate, a refinement can be applied by dividing the total number of individuals by the room's capacity, establishing the number of groups accordingly. After computing the sum of standard deviations within each group, the algorithm selects the "i" individuals (equal to the room capacity) with the lowest standard deviations to occupy the same room.

In summary, the utilization of a hybrid approach involving both the greedy algorithm and backtracking has been detailed for nursing homes allocation. It is anticipated that this method will foster harmonious interactions among elderly residents and concurrently alleviate administrative burdens on management personnel.

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