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Optimizing the car dispatching in elevator group control systems of tall buildings.

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Abstract- *The presence of tall buildings in the business centres of the main cities of the world are very common nowadays . Such buildings require the installation of numerous lifts that are coordinated and managed under a unique control system. Population working in the buildings follows a similar traffic pattern generating situations of traffic congestion. The problem arises when a passenger makes a hall call wishing to travel to another floor of the building. The dispatching of the most suitable car is the optimization problem we are tackling in this paper. We develop a viral system algorithm which is based on a bio-inspired virus infection analogy to deal with it. The viral system algorithm is compared to generic algorithms, and tabu search approaches that have proven efficiency in the vertical transportation literature. The experiments undertaken in tall buildings from 10 to 24 floors, and several car configurations from 2 to 6 cars, provide valuable results and show how viral system outperforms such soft computing algorithms.*

I. INTRODUCTION

Transportation is a classic discipline with a long tradition in the industrial engineering research. A particular case of transportation is vertical transportation which considers the vertical transportation of passengers or freight in a building through its floors. In fact, in the late years, the rapid growth of the building industry and associated technologies has been demanding parallel growth in the field of vertical transportation. The progressive price increase in the urban centres of the larger cities makes the necessary intensive ground exploitation by means of the construction of tall buildings (see figure 1 depicting an image of the Cyber Hub, Gurugram City). To manage with the vertical transportation system of such buildings, the installation of synchronized elevator groups in is a usual practice.

Figure 1 : A landscape of Gurugram skyscrapers fromCyber Hub, Gurugram, Haryana, India.

Figure 2 : City Skyline of Mumbai , Maharashtra, India.

The main objective of an optimal elevator group control system (EGCS) is to provide a good quality of service to its passengers (see CIBSE Guide, 2005). The problem tackled by every EGCS is to solve the assignment process of a car of the elevator group to a hall call made by a passenger wanting to travel from a floor to other different floor in the building. When a passenger presses a landing call button of the panel in the hall, he/she expects that a car of the EGCS will arrive in a few seconds. This assignment process must be done analysing the different options and selecting the most suitable car to serve the person having issued the call. This assignment must be done optimizing the waiting times that the passenger will experiment. The most common optimization criterion (Cortés et al., 2006) for quality of service in elevator group controllers is the reduction of the average journey time (AJT) which consists of the waiting time queuing in the hall (average waiting time, AWT) plus the travel time to destination inside the car (average travel time, ATT).

The average waiting time (AWT) is the actual time a prospective passenger waits after registering a hall call until the responding elevator doors begin to open.

The problem that an EGCS must tackle consists of the allocation of a car of the group to a hall call made by a passenger based on a criterion such as the AJT and it is a NP Hard problem that presents n ^ k possible combinations for n floors and k lifts, and therefore it is an extreme computational complexity problem. In recent years, research on EGCS for vertical transportation in buildings is gaining a considerable interest from the scientific community. Here, generic algorithms have been widely used providing good and valuable results since a long time and research continues being undertaken in this field. Other techniques such as particle swarm optimization have been also applied as well as immune systems algorithms.

Recently, viral systems which are a novel bio-inspired technique has been introduced in the literature devoted to applied bio-inspired algorithms providing successfulapplications to the Steiner problem in networks, knapsack problem vehicle routing problem or scheduling problems.

We have applied this novel technique to deal with optimization of the hall call-car allocation systems of the EGCS. Following the method cells are defined as the feasible solutions that are encoded from the Cortes. Et al. strategy that has been widely accepted by the vertical transportation scientific community.

The remaining of the paper deals with the presentation of the problem and the adaptation of the viral system algorithm to solve the car-call allocation optimization in EGCS which shall be shown in section 2. Then, in section 3, experimental results are provided for tall buildings from 10 to 24 floors, and several car configurations from 2 to 6 cars. Finally, the main conclusions are drawn in the final section.

II. LITERATURE SURVEY

The literature review for this study was conducted on below mentioned scenario -

2. The viral system approach to optimize the elevator group control system

The elevator group control system of a building includes a set of microchips in controllers to determine which car of the group should serve each hall call. When passengers arrive to the hall of the building and press an up or down button the EGCS must assign a car of the group to such call.

Passengers arrive to a building following specific traffic patterns. Four main patterns are traditionally catalogued. Figure 2 shows usual patterns is an office building. Uppeak traffic characterizes a larger than average number of up landing calls, it typically appears when workers leave the building to go back home. A lunchpeak traffic patterns takes place in the middle of the day, and it is due to the appearance of up and down peaks, it appears usually for lunching at midday. Finally interfloor traffic corresponds to the rest of the day. This pattern is characterized for a low demand in both directions.

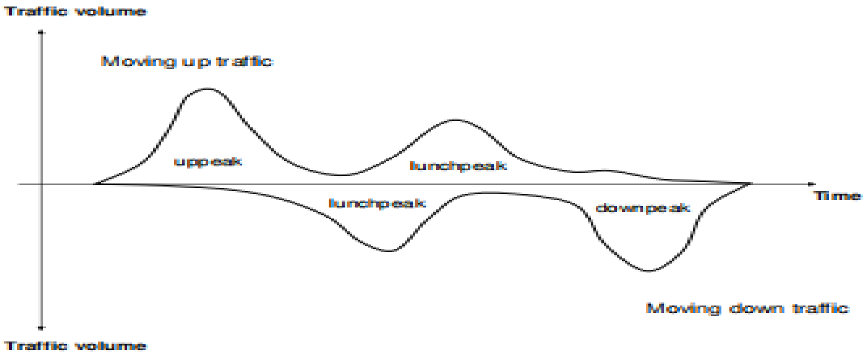

Figure 3 - Traffic pattern in an office building.

This section presents an algorithms that assigns the most suitable car to a hall call made by a passenger arriving to the hall of a building.

2.1 Cell Genome definition

The possible solutions for the allocation of a hall call to a car are encoded according to binary array. One array is associated to each car in the elevator group, is defined by representing the up and down calls at each floor that are assigned to this specific car. So, the length of each array is equal to 2 x (Number of floors - 1).

So, the first number of floors - 1 integers corresponds to the hall calls in the upward direction from the ground floor to the highest floor. The second Number of floors - 1 integers correspond to the hall calls in the downward direction from the highest floor to the ground floor. Figure 4 depicts the solution encoding.

The array holds the information referring to the hall calls by means of a binary codification. A bit 0 indicates no hall call at the floor, and a bit 1 indicates an existing hall call at that floor.

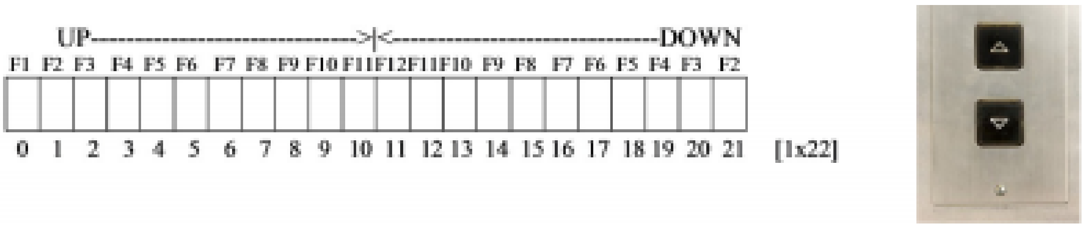

Figure 4 - Solution encoding for a twelve storey building corresponding to one car of the group and its associated physical button box.

2.2 Evaluation of Cell fitness

Each possible car-hall call allocation (cell) is evaluated following the methodology described in Bolat et al (2011), which has been proved to be an easy-to-implement and fast-to-compute technique.

Given parameters -
L1 - ground floor level
L2 - highest down hall call level
L3 - number of down hall calls between L1 & L2.
L4 - highest up hall call level
L5 - number of up hall calls between L1 & L4.
L6 - lowest down hall call level
t - door opening and closing time
tp - passenger transfer time
Hct - Highest car trip time
Lct - Lowest car trip time

The cell fitness is calculated depending on the type of passenger movements.

Table 1. Fitness evaluation as function of the traffic pattern in the building

Uppeak traffic pattern	Downpeak traffic pattern	Lunchpeak or interfloor traffic patterns
$f_i = t(L_4\text{-}L_1) + t_p(L_5\text{-}L_1)$	$f_i = t(L_2\text{-}L_1) + t_p(L_3\text{-}L_1)$	$f_i = t(L_4\text{-}L_1) + t(L_2\text{-}L_4) + t(L_2\text{-}L_6) + t_p(L_3\text{+}L_5\text{-}L_1)$

$$f_{group} = \frac{\sum_{i=1} f_i}{n}, \text{being } n \text{ the number of cars in the group}$$

$$f = k_1 \cdot f_{group} + k_2 \left(Hct - Lct \right)$$

III. EXPERIMENTAL OBSERVATIONS AND RESULTS

The experimentation was carried out using an Intel Pentium M Processor 740 at 1.73 GHz with 2 GB RAM, and Algorithms were encoded using software Matlab version 7.0

Tests were carried out for tall buildings from 10 to 24 floors at 3.3 metres of distance. We also considered different car configurations for the EGCS : 2,3,4 and 6 cars.

Table 2 gives the main specifications of the building and elevators respectively. Total time of a car stopping is given by ts = t open + t close + tp , where t open is the time for opening the door , t close is time for closing the door , tp is the time for passenger transfer.

Parameters of the viral system algorithm were calibrated to the following values (table 3) after testing and trying with different combinations. The algorithm was 10,000 items iterated.

Table 2 - Specification of elevator system

Items for elevator system	Value
Car capacity (people)	8
Time of travel between floors	4.5 (s)
Time for opening door	2.5 (s)
Time for closing door	3 (s)
Time for passenger transfer	3 (s)

Table 3 - Specification of elevator system

Parameter	Value
Lytic probability / Lysogenic probability	Plt = 0.7/plg = 0.3
LNR (limit of nucleus - capsids)	15
LIT (limit of iterations)	10
Antigenic response probability	pan = 0.053
Single Replication probability	pt = 0.7

Average journey time analysis is provided in Table 4 for each approach for buildings that have 10 to 24 floors and 2 to 6 cars.

Table 4. Average Journey Time comparison

Floors	2 cars				3 cars				4 cars				6 cars			
	GA[1]	TS[2]	PTS[3]	VS[4]	GA	TS	PTS	VS	GA	TS	PTS	VS	GA	TS	PTS	VS
10	58.5(SPC) 61.5(TPC) 58.5(UC)	58.5	58.5	45.5	41(SPC) 40(TPC) 39(UC)	42.0	41.0	31.4	37.5(SPC) 35.25(TPC) 37.5(UC)	41.3	31.5	26.8	32.5(SPC) 31.5(TPC) 31(UC)	33.0	27.5	17.7
12	60(SPC) 60(TPC) 60(UC)	63.0	64.5	57.9	46(SPC) 47(TPC) 47(UC)	46.0	45.0	34.3	42(SPC) 38.25(TPC) 39.75(UC)	40.5	42.0	32.5	36(SPC) 32.5(TPC) 39(UC)	37.0	31.5	22.4
14	82.5(SPC) 75(TPC) 76.5(UC)	82.5	76.5	71.9	54(SPC) 53(TPC) 54(UC)	56.0	51.0	47.7	46.5(SPC) 45(TPC) 45.75(UC)	46.5	46.5	39.3	40(SPC) 40(TPC) 40(UC)	48.5	40.5	27.0
16	72(SPC) 75(TPC) 72(UC)	72.0	72.0	86.8	56(SPC) 52(TPC) 61(UC)	60.0	52.0	58.7	48.75(SPC) 46.5(TPC) 48(UC)	48.8	48.8	45.0	49.5(SPC) 45.5(TPC) 46(UC)	49.5	47.5	33.8
18	90(SPC) 90(TPC) 84(UC)	87.0	87.0	66.6	66(SPC) 65(TPC) 66(UC)	65.0	64.0	59.8	60(SPC) 63.75(TPC) 61.5(UC)	60.8	59.3	57.0	49(SPC) 53.5(TPC) 61(UC)	67.5	50.0	37.7
20	93(SPC) 93(TPC) 99(UC)	108.0	99.0	99.6	89(SPC) 74(TPC) 84(UC)	84.0	76.0	60.3	75.75(SPC) 69(TPC) 66(UC)	74.3	59.8	64.6	66(SPC) 64.5(TPC) 67.5(UC)	70.0	66.5	43.4
22	105(SPC) 120(TPC) 105(UC)	105.0	109.5	96.6	87(SPC) 85(TPC) 81(UC)	87.0	89.0	82.4	78.75(SPC) 77.25(TPC) 76.5(UC)	81.0	75.8	60.4	68.5(SPC) 69.5(TPC) 66.5(UC)	71.0	64.5	47.9
24	115.5(SPC) 115.5(TPC) 115.5(UC)	115.5	111.0	117.3	95(SPC) 89(TPC) 90(UC)	90.0	90.0	68.1	80.25(SPC) 78.75(TPC) 73.5(UC)	87.8	74.3	72.7	64(SPC) 67(TPC) 65.5(UC)	66.5	63.0	53.4

[1] Genetic algorithm (Bolat et al., 2010); SPC: single point crossover; TPC: two point crossover; UC: uniform crossover
[2] Tabu search (Bolat et al., 2011)
[3] Probabilistic tabu search (Bolat et al., 2011)
[4] Viral system

The results confirm that the viral system approach outperforms the genetic and tabu approaches practically in every configuration. Results provided for VS are only slightly worse for specific configurations given by two cars. Just, these cases represent those situations where an EGCS is less necessary and soft computing approaches can be avoided by using traditional heuristic dispatching rules. When the complexity of the EGCS increases, as well as the height of the building, VS provides very interesting results outperforming the AJT provided by other methods.

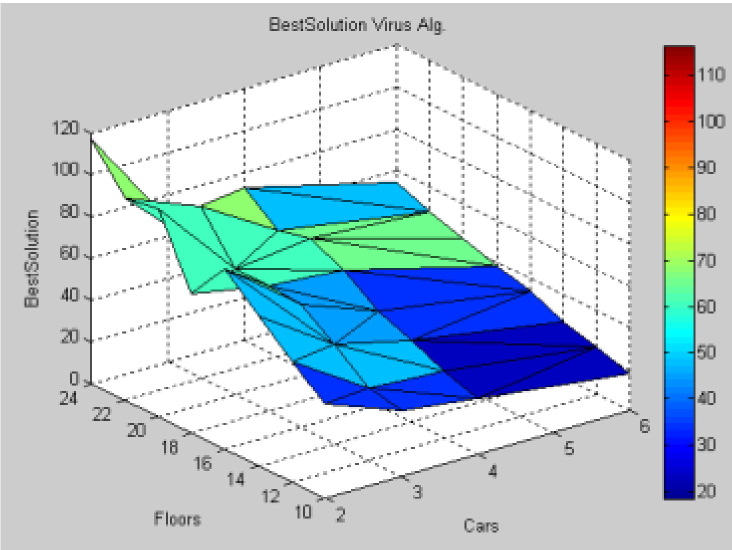

Figure 5 - VS AJT evolution with respect to the number of cars in EGCS and the floor in building

Figure 5 depicts the evolution of AJT when the number of floors grows and the number of cars decreases. The increase of AJT is especially significant for the case of 2 cars and more than 16 floors.

The computational required for each approach is provided in table 5 for the considered configurations. PTS produced the quickest results for low car configurations (2 and 3 cars) although its computational time increases significantly for higher configurations. In general terms, GA provided the best results from a computational perspective, specifically when the size of the group grows (cases with 4, and especially 6 cars). The computational time provided by the viral system algorithm was better than the results provided by the tabu approaches especially for those complex cases (that is, 4 to 6 cars in the group and tall buildings). Result provided by the VS were bounded in general terms and did not rise as significantly as the tabu approaches following a more moderate increase as the genetic approaches.

Table 5. Computational time comparison

Floors	2 cars				3 cars				4 cars				6 cars			
	GA[1]	TS[2]	PTS[3]	VS[4]	GA	TS	PTS	VS	GA	TS	PTS	VS	GA	TS	PTS	VS
10	1.6 (SPC) 3.0 (TPC) 1.6 (UC)	3.2	0.5	6.5	2.6 (SPC) 2.5 (TPC) 2.4 (UC)	4.4	0.8	8.1	2.9 (SPC) 2.2 (TPC) 1.8 (UC)	9.3	6.2	9.7	1.9 (SPC) 1.9 (TPC) 2.0 (UC)	43.6	27.3	12.6
12	2.0 (SPC) 1.9 (TPC) 2.2 (UC)	6.5	0.4	6.6	2.3 (SPC) 2.5 (TPC) 2.5 (UC)	4.8	0.8	8.1	1.7 (SPC) 1.7 (TPC) 1.7 (UC)	22.0	2.9	9.7	2.0 (SPC) 2.5 (TPC) 2.0 (UC)	57.2	22.3	13.0
14	2.2 (SPC) 2.0 (TPC) 2.0 (UC)	5.0	0.5	6.5	2.2 (SPC) 2.2 (TPC) 2.6 (UC)	9.2	0.8	8.1	1.8 (SPC) 1.7 (TPC) 1.5 (UC)	30.7	4.7	9.8	2.0 (SPC) 2.0 (TPC) 2.0 (UC)	81.6	29.6	12.9
16	2.1 (SPC) 2.3 (TPC) 2.1 (UC)	6.8	0.5	7.0	2.2 (SPC) 2.4 (TPC) 2.2 (UC)	9.9	0.7	8.3	1.8 (SPC) 1.7 (TPC) 1.7 (UC)	28.9	5.1	9.8	1.8 (SPC) 1.9 (TPC) 1.7 (UC)	104.1	16.9	13.0
18	2.3 (SPC) 2.3 (TPC) 2.0 (UC)	4.8	0.6	6.5	2.4 (SPC) 2.3 (TPC) 2.2 (UC)	13.5	1.5	8.3	1.7 (SPC) 1.7 (TPC) 1.8 (UC)	67.5	8.4	9.9	1.9 (SPC) 1.9 (TPC) 2.1 (UC)	183.5	46.2	13.0
20	2.0 (SPC) 2.3 (TPC) 2.1 (UC)	4.6	0.6	6.8	4.8 (SPC) 2.4 (TPC) 2.4 (UC)	13.0	1.9	8.4	1.7 (SPC) 1.9 (TPC) 1.9 (UC)	57.0	6.3	9.8	2.1 (SPC) 2.1 (TPC) 1.9 (UC)	167.8	57.5	13.1
22	2.2 (SPC) 2.2 (TPC) 2.0 (UC)	5.4	0.6	6.6	2.3 (SPC) 2.5 (TPC) 2.4 (UC)	9.4	2.0	8.3	1.9 (SPC) 1.8 (TPC) 1.9 (UC)	50.4	14.0	9.9	1.8 (SPC) 1.9 (TPC) 2.1 (UC)	173.0	60.8	13.2
24	2.3 (SPC) 2.1 (TPC) 2.0 (UC)	6.1	0.7	7.0	2.7 (SPC) 2.8 (TPC) 2.5 (UC)	16.3	2.1	8.3	1.8 (SPC) 1.8 (TPC) 1.8 (UC)	89.4	12.8	10.0	1.8 (SPC) 1.9 (TPC) 2.5 (UC)	134.4	47.8	13.3

[1] Genetic algorithm (Bolat et al., 2010); SPC: single point crossover; TPC: two point crossover; UC: uniform crossover
[2] Tabu search (Bolat et al., 2011)
[3] Probabilistic tabu search (Bolat et al., 2011)
[4] Viral system

Figure 6 shows the computational time evolution with respect to the number of floors , and the number of cars. The higher values are obtained for cases of higher number of cars, and the tallest buildings.

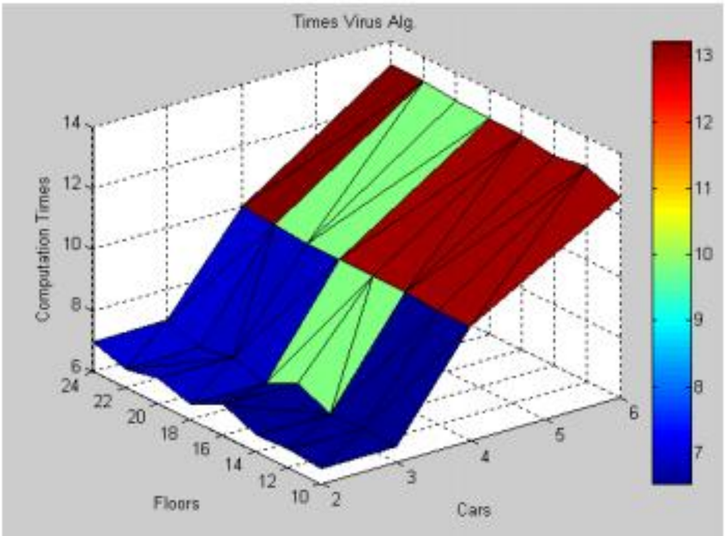

Figure 6 - Computational time evolution with respect to the number of cars in the EGCS, and the floors in the building.

IV. CONCLUSION

This paper presents the application of a novel bio-inspired algorithm called viral system to the car dispatching problems for multi-cars elevator group control systems. The problem arises when passenger makes a landing call in the hall of the building wanting to travel from a floor to other floor of the building. The algorithm makes use of a binary wanting to travel from a floor to other floor of the building. The algorithm makes use of a binary encoding strategy to identify the cars being assigned to the landing calls, and of a fitness estimation allowing a quick evaluation. The estimation requires the identification of the type of traffic pattern in the building : uppeak, downpeak, lunchpeak or interfloor.

The viral system algorithm provided valuable figures for the average journey time (AJT) when was compared to the genetic algorithms , and tabu search approaches that have proven efficiency in the vertical transportation literature. The experiments were undertaken in tall buildings from 10 to 24 floors, and several car configurations from 2 to 6 cars, and the better results were obtained for the more complex configuration implying larger car group and taller buildings.

The computational time required by the VS to find the next best solution was lower than the tabu approaches, and it was in the order of magnitude of genetic implementations when using 1000 iterations for the VS. It can be said that the required computational time was adequate when dealing with a real time problem such as elevator group control system. In addition, better results attending to the computational time were again obtained for the more complex configurations. Even more, it has to be noted that the results obtained with a CPU can be limited with respect the real industry operation. In practice, real implementations are installed or proprietary microchips requiring lighter implementations. Bounding this fact, the real implementations of the VS algorithm in the industry appears to be possible. For example, in real cases an alternative can be calculating the fitness not every-time but in a selective manner, or stopping the algorithm after a lower number of iterations. All these decisions are very dependent on the computational speed of the electronic microchips installed by the company in the controller, and could affect the quality of the implemented algorithm.

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