The use of Genetic Algorithms in the application of a matematical model to optimize the management of overbooking

I. Sánchez Berriel[1] V. Gutiérrez Rodríguez[2]
A. M. Gil Padilla[3] R. Berriel Martínez[4]

Abstract

In this research we deal with the use of the Genetic Algorithms to optimize the problems originated by overbooking phenomena, in the hospitality industry. We are trying to support the business to minimize the cost generated as a consequence of overbooking situations and optimize the relodging of clients to other establishments. In accordance with the results obtained we can assign, in a optimun way, each guest to an establishment. As well we analyze the designed GA and reports results in determining near-optimal in a sudied hotel association.

Introduction

The tourist sector in the Canary Islands gives a major added value to the "PIB" of the region and their own intrinsic characteristics that define the tourist activity, this sector shapes itself like that which has a considerable knock on effect on other sectors of the economy. From this point of view the tourist sector itself acts like a machine of comercial activity, the construction, the transport, the communications, etc., for this it is necessary to have certain infrastructures that permit us to improve the quality of service that we are going to offer to the touristic demand and at the same time improve the image of the tourist destination, the Canary Islands, as well as the standard of living of the citizens resident in the region.

The arrival of tourists on a grand scale is causing problems of overbooking that could be the consequence of bad planning on the part of some lodging establisments in determining the levels of occupation expected for the places offered, but they can, also, be due to the external conditions which are difficult to predict. The economic costs and others that this implicates for the enterprises of the sector and for the region as a tourist destination could be very elevated.

On the base of all the aforementioned, we conducted a practical analysis, on which we designed and runned an mathematic model that will help a Decision Support System (DSS) in relation with the relodgint or redistribution of customers that are confronting to the overbooking situation. This work conform a second phase in the project of development of mentioned DSS that we proposed in a before research (see [1]). That system will be integrated as a support element in the strategy of differentiation and improve the quality of the customer service based on processes of technological innovation. The mathematic model used is based on the optimization of the fitness function, where we collect internal and external factors that the tourist establishments must consider to determine the right level of occupation.

Creation of the problem

The tourist establishment have a fixed offer of rooms available to be sold. The average of the aforementioned offer is difficult to determine because we must know: (1) the basic rate of occupation, wich indicates the percentage of roorms used in a determined night; (2) the rate of occupation of beds, which establishes the number of guest who are staying, as well as the percentage of the maximun capacity; and (3) the income for occupation, comparing the quantity received per room and per night with the theoretical month (see [2]). The principal objective of the business is to achieve the maximun level of occupation as well as the usage of complimentary services on offer. To achieve this objective, they offer their places through different agents (fundamentaly tour-operators and travel agencies) with whom they establish contractual relations which makes the distribution and the sales of places easier.

However, when they think that the level of occupation of their establishments is low, they try to work with a margin of places which allows them to cover unpredictable situations.

For this reason, at certain times of the year, situations of over-contraction are produced which is the origin of the overbooking problem, consisting, basically, in contracting with another agent a superior number of places than that which are really on offer, with the objective of assuring maximun occupation (see [3]).

The overbooking phenomena has become general practice in the mayority of the business of the sector, causing a seasonal problem that could have drastic consequences for some of the business who suffer it. For this reason, it is neccessary to know: (1) in which situations overbooking is produced; (2) which costs are derived for the establisments that incur this practice; (3) how to solve the problem once it has been created; and (4) what measures to adopt to prevent and manage the overbooking situation.

Situations where overbooking is produced

Generally, the establishments make a prediction of the expected demand and based on this, they control the places available for their sales by the management of places, and at the same time, they try to coordinate the relations which the maintain with the different tour-operators andt agents, with the objective of not desviating from the established predictions. However, if the relations that they have with others do not coordinate correctly, situations can be produced that lead towards over contraction. As a consequence of this situation an important phenomena is originated that harms the grade of occupation which depends on the cancellations and the no showing of clients wha have reserved a place and do not appear (see [4]). In relation to the cancellations, it is neccessary for the tour-operators cancel the reservation, otherwise the origination of overbooking is likely.

Costs as a consequence of overbooking

For this tourist subsector, the penalties that can be established for the state bodies (Dirección General de Ordenación de Infraestructura Turística), as well as for the autonomous bodies (Consejería de Turismo del Gobierno Autónomo de Canarias) are specify by low. But however the hospitality business can to act with flexibility.

Obviously the divertion of clients to other establishments is a form of solving the problem but it does not eliminate the negative consequences that are derived from this practice for the affected establishments, like the repercusion on the image of the establishment that could remain damaged, the repetition of the demand and the improvement of the quality of service that could be affected in turn damaging, if the practice becomes extensive, in the subsector the global image of the tourist destination. Therefore, of the cost which are derived for the establishments as a consequence of the over contraction a miticulous analysis must be carried out with the objective of establishing the opportune measures allowed to reduce them. In this way, the overbooking of lodging give rise to different types of costs directly related to the situation. Firstly, the cost of relodging of the client, which means place the client in another establishment as well as other costs associated to the search of lodging for this client (communication cost, etc..); secondly the cost of compensation to the client, which obliges the establishment to localize them a place if the client insists that he want to be lodged in the same establishment or instead in another establishment, when they agree to be moved to one of the same or superior category; third the cost of the image for the establishment, that materializes in the loss of future business for the establishment as a consequence of the effects produced by the clients actions, who can opt no repeat the stay or instead carry out a negative campaign in their area of origin; and finally, the cost of tour-operator penalty plus the cost produced by the penalty of the corresponding body, if the problem is reported.

Solution to the problem once pased

The most common method used to solve the situation of overbooking consists in diverting the clients to other establishments, that can have the same proprietary (in the case of chains) or tho the competition (in the case of an independant establishment) with availibility of places, in the same location or another of the same destination. In this respect, they must take into consideration that the client has the right to demand similar accomodation and never an inferior category to the one which was previosly contracted (see [5]). In these case where the client insists in his wish to stay in the establishment previously chosen, it is necessary to make suitable one of the rooms which are out of service or install them in an "suite" room of available.

Enviroment of work

To develop the present work we approached to the hotel establishments (3 and 4 stars), in the tourist zone of San Bartolomé de Tirajana and Mogán in Gran Canaria and Puerto de la Cruz in Tenerife, where we interviewed the directors and the managers of the comercial area. We focused our work on the aforementioned categories of hotels, because they are the categories most demanded and present the highest levels of occupation (see [6]).

Description of the problem

Based on everything seen before, it is neccessary that establishments plan the admission of reservations. To this process we must consider the following problems which present

themselves: (1) how to guarantee the maximun occupation; and (2) what to do with a client whose place in the establishment has been sold and is not available.
To solve the first problem the hospitality business to offering more places than are really at their disposition depending on the forecast of the confirmation, the percentage of the aforementioned 300% or, in some cases, superior. However, the forecast are subject to errors that can provoke loses, in this case the second problem presents itself which affects, especially the independent establishments of the same category or superior.
We work with the establishment who are in chains or with those who have associated to solve the problem. Therefore, they prepare an inventary of places required based on the places offered by the establishment with places vacant. The problem that occurs is relocating the affected clients due to the overbooking in the places available, in a way that minimizes the costs of the mistakes in the forecasts of which they have planned the offer. That is to say, given an associated establishment with a problem (or various) of overbooking in one determined day, the system will proportion how the affected clients will be resdistributed in the places that are not occupied in other establishments, to minimize the cost which this presents.
Among the possible costs which derive when the problem presents itself we select the following:

COSTS	INTERPRETATIÓN
Relodging	What the room in another establisment costs
Associated to relodging	Transport costs to the other destination
Other associated costs	Costs generated by the new reservation
Compensation	The indemnisation directly to the client
The loss of business	Income which in no longer earned
The loss of image	The reduction in the quality of the product

Formulation of the problem

We gather the aforementioned in a simplify mathemathic model, that we will describe next. We create an optimisation problem to solve the overbooking cases that arise in a day in the associated business, each one is represented by H_j. We will minimize the cost for desviate the clients from an establishment to others associeted establishments. To construct the objective function we dispose an inventory with overbookings and free places in the association.
We consider the next parameters:
N: Number of establishments associeted in the agreement.
n: Number of hotels with overbookings.
m: Number of hotels with free places.
P: Cost of loss of business.

Q: Cost of loss of image.
M: Total number of cost to consider (M=4).
O_j: Number of overbooking places of the establishment H_j.

B: Number of total overbooking places in the imoplicate hotels, $B = \sum_{j=1}^{n} O_j$

V_j: Number of free places in H_j

A: Number of total free places of the implicate hotels H_j $A = \sum_{j=1}^{N} V_j$

C_{1k}: Cost of relodging to the establishment H in the establishment H_k
C_{2k}: Cost of place to the establishment H in the establishment H_k
C_{3k}: Cost associeted (comunication, etc...) to the establishment H in the establishment H_k
C_{4k}: Cost of compensation to the establishment H in the establishments H_k

$C_{ij} = \sum_{k=1}^{M} C_{kij}$ cost of relodging overbooking j in place i.

$$x_{ij} == \begin{cases} 1 \text{ if overbooking j is lodged in place i} \\ 0 \text{ in another cases} \end{cases}$$

We can write the simplify formulation of the problem that we are working, in the next form:

$$\min \sum_{i=1}^{A} \sum_{j=1}^{B} C_{ij} x_{ij}$$

$$\text{subject to: } \sum_{k=1}^{B} x_{jk} \le 1 \quad j = 1,\ldots,A$$

$$x_{jk} \in \{0,1\} \quad j = 1,\ldots,A \quad k = 1,\ldots,B$$

$$\sum_{j=1}^{A} x_{jk} \le 1 \quad k = 1,\ldots,B$$

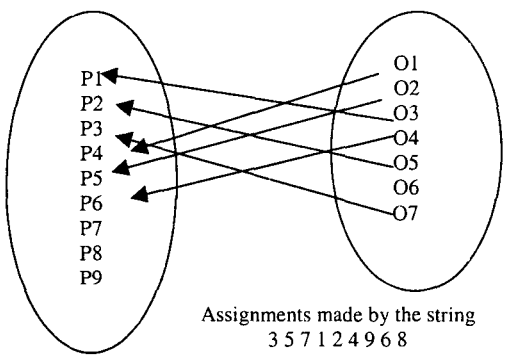
Solving the problem

To solve the problem we use Genetic Algorithms because it is robust searching tool which additionally proporciontates a group of solutions very close to the optimun of the problem, that will permit us to present the client different options with different minimun costs for the establishment (see [7]). We describe the special considerations that must be done in the application of an GA, especilly, the codification of the variables of the problem and the crossover operator that will be used.
The GA start with a random population of candidate codified solutions from where they produce new generations of better solutions than the previous one, untill to arrive, in a robust way, to the optimal solution (see[8]).

The constraints can be solved in three ways:

a) Transforming the problem with constraints into another without their by associating a penalty with all violations. However, it may be the algorithm spends a sgnificant amount of time evaluating individuals.
b) Appliying special repair algorithms to correct no-feasible solutions. In many times they are computationally hards and may be as difficult as solving the original problem.
c) Using special codifications to keep feasibles solution along the evolution. However, sometimes the constraints are not easy to incorporate in the code of the individuals.

To this work we choose the third option, coding one individual by a string of integers, the string size will be the number of free places in the associated establishments. Each location represents one availaible room in the association, each element in the string is the overbooking that will be lodged in the corresponding place. Values in the string greater than the number of overbooking means free places without overbooking assingnment. We show the meaning of the individual 3 5 7 1 2 4 9 6 8 in the following figure:



This kind of string will be a feasible solution if it does not repeat any value, we take this in account in the initial random population, as well as in the recombination operators: crossover and mutation.

The selection operator identifies the strongest individuals of the present population that will be choosen like parents in the next generation and it originates an intermediate population $P'(t)$ from the population $P(t)$. The crossover operator choses, in random way, a pair of individuals in the previously choosed to exchange the genetic material of two parents and transmite it to their offsprings.

The objective of the crossover operator is explore the space of the search by the recombination, against the explotation of the space of the search developed by the selection. We have employed crossover operator used for Mühlenbein, Georges-Schlenter and Krärmer in the travel salesman problem consists of to exchange two segments between tow parents in their offspring, next the string corresponding with the opposite ancestor will be copy in the same order from the beginning, omitting symbols already present. Using this way we will obtain feasibles populations in next generation maintaining information from their fathers but opening new search paths.

3	5	7	1	2	4	9	6	8
5	8	4	3	2	1	6	7	9
x	x	x	3	2	1	6	x	x
x	x	x	1	2	4	9	x	x

Block containing ancestor information

Offspring

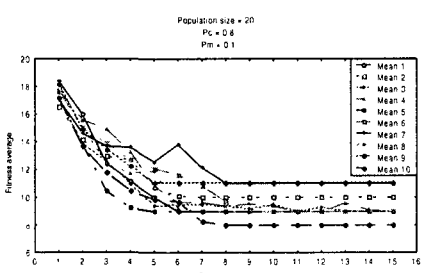
5	7	4	3	2	1	6	9	8
5	8	3	1	2	4	9	6	7

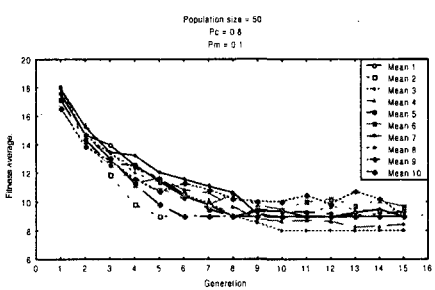
We also use a mutation operator maintaining the feasibility in the offspring that allow introduce diversity in the new porpulation, it works as follow:

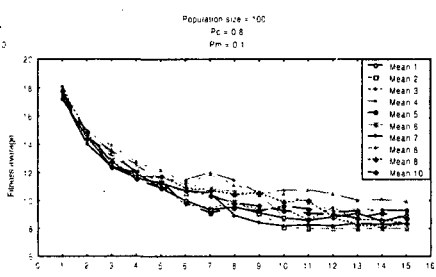
3	5	7	1	2	4	9	6	8
2	4	9	6	8	3	5	7	1

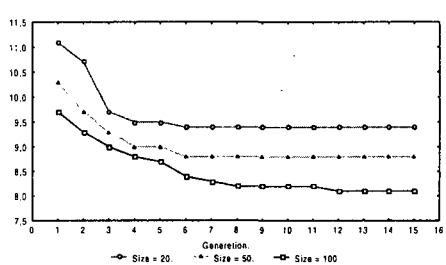
Experimental results

We have implemented a GA using code and recombination operators explained in the previous section besides tournament selection. It has been used crossover probability 0.8 and mutation probability 0.1. The number of individuals in the competition are 4. That operators and parameters have been experimented with 7 overbookings that will be loged in 9 availaibles roms in 4 hotels.
In the graph are represented results for differents executions of the algorithm for population size 20, 50 and 100. We drawed in graphs 1, 2, 3 fitness average in each execution and in graph 4 the best indiviual fitness averages obtained in each generation for the 3 population sizes.









We can observe the performance of the algorithm that converges in a few generations and obtains the best results for population size 100 as well as with 50 individuals, we have good results because always reach optimun or near –optimun solution.

Conclusions

The quality of the tourist service and the image of the tourist destination Canary will be afected, in the future, if the hospitality business´ do not introducing changes that give solution to the problem of overbooking. We combine different options of relodgin with minimun costs associated in the model that we proposed and we obtained good results very close to the optimum solution.

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1. Dpto de Estadística, Investigación Operativa y Computación. ULL, **isanchez@ull.es**
2. Dpto de Estadística, Investigación Operativa y Computación. ULL **vgutier@ull.es**
3. Dpto Economía y Dirección de Empresas. ULPGC, **agil@empresariales.ulpgc.es**
4. Dpto de Matemáticas. ULPGC. **rberriel@dma.ulpgc.es**