Using Particle Swarm Optimization Algorithm in Manpower Planning for a Call Center in Healthcare Service

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Abstract. In the call center of private hospitals, they have an advanced assignment program. The program can make patients more convenient to receive healthcare services. When the number of caller has become larger, the hospitals have some problems. It is very difficult to determine how many operators that we needed to respond the calls. It has highly abandon rate when patients need to wait for a long time, and it leads to the loss of opportunity. In this paper, we formulate a mathematical programming model for the problem by using mixed-integer nonlinear programming. And we focus on using Particle Swarm Optimization (PSO) algorithm to solve the mathematical model. This method can solve the model faster. So, the hospitals can quickly and promptly to determine the optimal number of operators.

Keywords: Particle Swarm Optimization Algorithm, Healthcare Service, Manpower Planning

1. INTRODUCTION

Nowadays, call center has been a more and more important role whether in any kind of industry. In the hospital, call center is also an initial communication bridge between the customers and a hospital. It can offer a convenient service to customers, make them can more quickly and easier to check some information of hospital's service. For instance, some service are rearranging an appointment and complaint/suggestion handling. When the number of inbound call increased, many hospital call centers would meet a problem. It is very difficult to determine how many operators that we needed to respond the increasing inbound call. If operators cannot serve the customers in time, the customers may quit the calls because they wait for a too long time. After the customers quit the calls, the operators need to call customers back to serve. This problem makes the abandon rate high and leads to the loss of opportunity.

And the operators in the hospital call center are different from others. They need to have sufficient training and education. It can make them be more professional at medical knowledge, then they can offer better service for customers. Furthermore, in view of people will decide whether to revisit due to the quality of service for the first time (Nah & Kim, 2013). So, how to systematically decide a good manpower for the call center is very important.

This paper consider three inbound call type and the maximum allowable abandonment rate of every time period to formulate a mathematical programming model for the problem. The model is formulated by using mixed-integer nonlinear programming. And we focus on using the Particle Swarm Optimization (PSO) algorithm to solve this mathematical model. It can make the hospitals more quickly and promptly to determine the optimal number of operators.

2. LITERATURE REVIEW

An advanced assignment program is very important for a hospital call center. When the number of inbound call increased, many hospitals call center do not have a systematic method to confirm whether the current operators are able to response the calls or not (Nah & Kim, 2013).

And the operators in the hospital call center are different from general call center. They have more sufficient training and education. So, they can be more professional at medical knowledge and then offer better service for customers. For example, the operators can find a suitable doctor for the patient quickly. Moreover, in view of people will decide whether to revisit due to the quality of service for the first time (Nah & Kim, 2013).

Furthermore, a hospital call center dose not only response the calls but also need to arrange many tasks for the operators(Moore et al., 2001). The hospital call center's competitive strength depend on experiences and instinct to decide the priority of tasks and when the task has to be done. In some hospital call centers, they are lack of these competencies. It will make a long waiting time for customers and abandonment rate increasing.

Several research considering only one type of inbound calls. Actually, there are many different types of inbound calls from various customers' demand. For example, some customers need to get more information enquiry, and rearrange an appointment. And other customers may want to complain or suggest some problem. These additional demand make operators serve the customers inefficiently (Aksin et al., 2007). So, much research focus on the manpower planning and allocation problem in the call center.

3. HOSPITAL CALL CENTER TASKS

The process of the hospital call center is presented in the Figure 1. When there are inbound calls from the customer, they are classified into three types: information enquiry rearranging an appointment and complaint/suggestion.

The first type of inbound call is information enquiry. When there is an information enquiry inbound call, the operators will reply to the customers at once. But not every time the operators have enough capacity to serve customers. They will ask customers to wait for some time until they have enough capacity to serve them. However, some customers cannot stand to wait for a long time, they may abandon the calls. So, the operators need to call back the customers to serve.

Next type is the rearranging an appointment. To handle this type inbound call, the operators need to check the database of hospital to rearrange the appointment for the customer. After checking and rearranging, the operators will call back the customers for their problem. This step is time-consuming because the operators have to communication with other department to reschedule.

The final type of inbound call is complaint call. The operators can collect many opinions from customers. But some opinions do not fall within the scope of their jurisdiction, they will transfer the call to the person in charge.

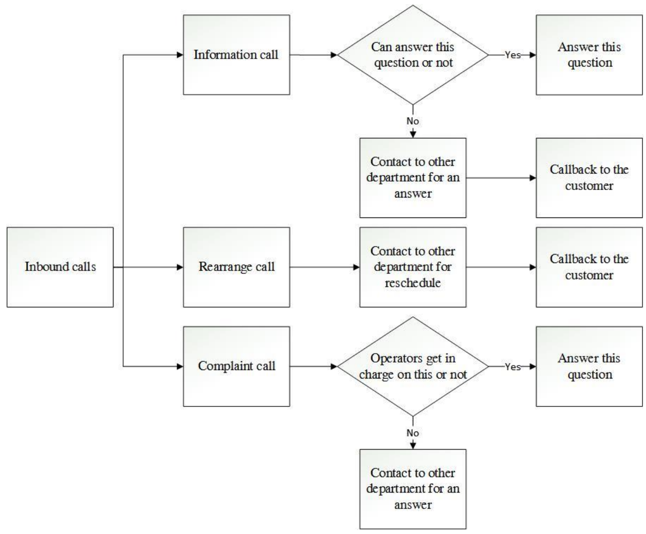

Figure 1: Hospital call center work process.

4. MATHEMATICAL MODEL FORMULATION AND NUMERICAL EXAMPLE

4.1 Mathematical model

In this paper, the mathematical model based on the model represented in (Booranadiloak et al., 2015). We consider three types of the inbound call and the maximum allowable abandonment rate to formulate a mathematical model, and all symbol as shown in the Table 1.

Table 1: Symbol for the model.

Symbol	Description
T	call center is open for 1 hour time period, $t \in T$
D	call center is open for working day , $d \in D$
K	call center is open for shift , k =1 , 2 , .. , K
I	the type of inbound calls , i = 1 , 2 , … , I

P_i	the probability of the type *i* inbound calls
F_i	the administration working time of the type *i* inbound calls
E_i	the operated time for the type *i* outbound calls
B_{td}	the volume of inbound calls assigned to time period (*t* , *d*)
u_{td}	the observed maximum allowable abandonment rate assigned to time period (*t* , *d*)
g_d	the hour needed for outbound calls assigned to working day *d*
α	the mean salary per operator every working day
β	the cost of waiting time
μ	the cost of the lost calls
z_{tdk}	the time period is non value added (*t* , *d* , *k*)
l_{td}	the loading of inbound calls assigned to time period (*t* , *d*)
W_{td}	the waiting time assigned to time period (*t* , *d*)
A_{td}	the abandonment rate assigned to time period (*t* , *d*)
$f_1(.)$	the function relation between waiting time and loading of inbound calls
$f_2(.)$	the function relation between abandonment rate and loading of inbound calls
x_{tdk}	the man hours of inbound calls assigned to time period (*t* , *d* , *k*)
y_{tdk}	the man hours of outbound calls assigned to time period (*t* , *d* , *k*)
v_{tdk}	the man hours of administration tasks assigned to time period (*t* , *d* , *k*)
N_k	the number of all operators assigned to shift *k*

Let *T*, *D* and *K* be the 1 hour time period *t* of the working day *d* in the shift *k* when the hospital call center is operating. And *I* is the type of inbound call, including information enquiry, rearranging an appointment, and complaint/suggestion. P_i and F_i are the probability and the working time for administration of call type *i* respectively.

We let *I* be three type of the inbound call, *i* is information enquiry rearranging an appointment and complaint/suggestion. And using the loading of inbound call (l_{td}) with $f_1(.)$ and $f_2(.)$ to get the predicted waiting time (W_{td}) and the predicted abandonment rate (A_{td}) (Nah & Kim, 2013).

We assume that N_k is the number of total operators' allocation for shift *k*. It is the sum of the total man-hours, inclusive of inbound call man hours, outbound call man hours and administrations task man hours assigned to every time period.

Minimize

$$\Omega = \alpha m \sum_{k=1}^{K} N_i \quad + \beta \sum_d \sum_t B_{td} W_{td} + \mu \sum_d \sum_t B_{td} A_{td} + \gamma \sum_d \sum_t B_{td} C_{td}$$

Subject to

$$l_{td} = \frac{B_{td}}{\sum_k^K X_{tdk}} \qquad \forall t, d \ , k \qquad (1)$$

$$W_{td} = f_1(l_{td}) \qquad \forall t, d \qquad (2)$$

$$A_{td} = f_2(l_{td}) \qquad \forall t, d \qquad (3)$$

$$A_{td} \le u_{td} \qquad \forall t, d \qquad (4)$$

$$\frac{\sum_t B_{td} A_{td}}{\sum_t B_{td}} \le u_d \qquad \forall t, d \qquad (5)$$

$$\frac{\sum_d \sum_t B_{td} A_{td}}{\sum_d \sum_t B_{td}} \le u \qquad \forall i, t, d, k \qquad (6)$$

$$g_d + P_i E_i \sum_t B_{td} \le \sum_t \sum_k y_{tdk} \qquad \forall i, t, d, k \qquad (7)$$

$$P_i F_i \sum_t B_{td} \le \sum_k \sum_t v_{tdk} \qquad \forall i, t, d, k \qquad (8)$$

$$N_k = x_{tdk} + y_{tdk} + z_{tdk} + v_{tdk} \qquad \forall t, d, k \qquad (9)$$

$$N_k \ge 0 \ \textit{ and integer} \qquad \forall k \qquad (10)$$

$$x_{tdk} \ge 0, \quad y_{tdk} \ge 0, \quad v_{tdk} \ge 0 \qquad \forall t, d, k \qquad (11)$$

The objective function of the model is to minimize the cost. It is including the operator cost, waiting line cost, call abandonment cost, and cost of opportunity loss.

The model is subject to some constraints. The first one is about the loading of inbound call. And it can get predicted waiting time (W_{td}) and predicted abandonment rate (A_{td}) in constraint (2) and (3). In the constraint (4), (5) and (6), they are the upper bound of hourly, daily and weekly allowable abandonment rates. The constraint (7) is the man hours for three type of outbound calls. The constraint (8) is the total man hours for each type of administration tasks. Finally, N_k is the number of total operators in the constraint (9). And the others are the non-negative constraints.

4.2 Numerical Example

We explain the problem of mathematical model by using a simple numerical example. The data is with reference to literature (Nah & Kim, 2013). Figure 2 shows the volume of inbound calls in every time period.

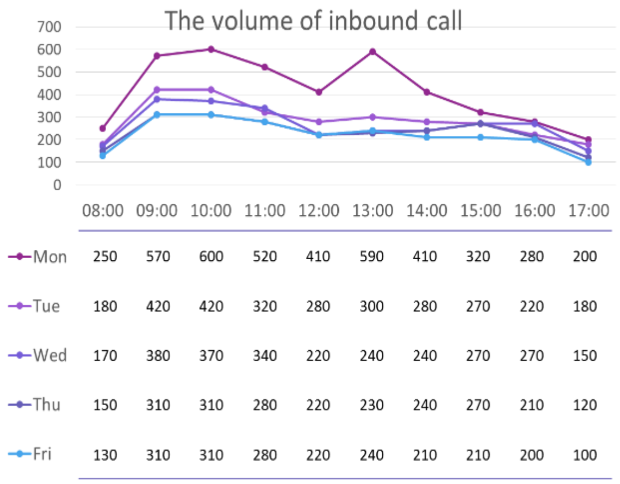

Figure 2: Observing inbound call every time period.

Table 2: Input parameter.

Parameter	Value
Rearrangement call probability ($\boldsymbol{P_{re}}$)	0.4
Information call probability ($\boldsymbol{P_{in}}$)	0.5
Complaint call probability ($\boldsymbol{P_{co}}$)	0.1
Operating hours of rearrangement ($\boldsymbol{F_{re}}$)	0.05
Operating hours of information ($\boldsymbol{F_{in}}$)	0.05
Operating hours of outbound rearrangement ($\boldsymbol{E_{re}}$)	0.05
Operating hours of outbound information ($\boldsymbol{E_{in}}$)	0.05
Salary ($\boldsymbol{\alpha}$)	80 $
Waiting cost ($\boldsymbol{\beta}$)	7.2 $
Cost of lost call ($\boldsymbol{\mu}$)	8.7 $
Mean hours of the outbound call ($\boldsymbol{g_d}$)	10

The Table 2 and Table 3 are the input data, including probability, operating hours of each type inbound call, salary, cost and abandonment rate. From below information, the mathematical model can be simplified representation.

Table 3: Maximum abandonment rate.

Period	Mon	Tue	Wed	Thu	Fri
8:00	22.5	16.5	15.0	13.5	12.0
9:00	22.5	16.5	15.0	13.5	12.0
10:00	22.5	16.5	15.0	13.5	12.0
11:00	33.8	24.8	22.5	20.3	18.0
12:00	45.0	33.0	30.0	27.0	24.0
13:00	33.8	24.8	22.5	20.3	18.0
14:00	16.9	12.4	11.3	10.1	9.0
15:00	16.9	12.4	11.3	10.1	9.0
16:00	16.9	12.4	11.3	10.1	9.0
17:00	16.9	12.4	11.3	10.1	9.0
u_d	22.5	16.5	15	13.5	12.0
u			15.0		

5. PARTICLE SWARM OPTIMIZATION AND COMPUTATIONAL RESULTS

5.1 Particle Swarm Optimization

Particle swarm optimization (PSO) is a nature Inspired Computing (NIC). In this paper, we focus on using Particle Swarm Optimization algorithm to solve the mathematical model. This method can solve the model faster.

In the PSO, we added some mechanism to make convergence more quickly. When updating the velocity, we consider three value of best fitness, including particle best (*pBest*), global best (*gBest*) and swarm best (*sBest*). It is depicted in the equation (12). In this equation, ω is inertia weight, c_1 is cognitive parameter, c_2 is social parameter, r_1, r_2 and r_3 are the random value from 0 to 1.

$$V_{t+1} = \omega V_t + c_1 r_1 (pBest - X_t) + c_2 r_2 (gBest - X_t) + c_3 r_3 (sBest - X_t) \quad (12)$$

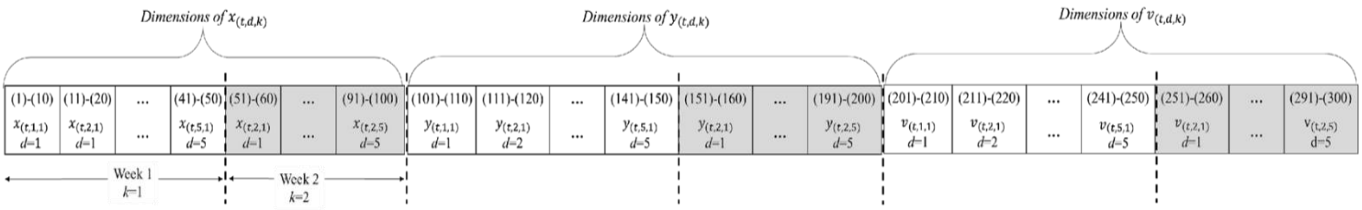

Figure 3: The dimension of PSO

For the dimensions in PSO, we assumed that every decision variable is the dimension in two shift. The decision variables are classified into three types of the man hours: inbound calls, outbound calls and administration tasks. And each type is composed by three parameters, including time period (*t*), day (*d*) and shift (*k*). For these parameters, the shift means a week. In the numerical example, there are 2 weeks, 5 days in every week, and 10 time period. So, there are totally got the 300 dimensions in this problem, as shown in the Figure 3.

The dimension 1 to 50 are the man hours of inbound calls (x_{tdk}) in first shift, then the dimension 50 to 100 are in the second shift. Similarly, the dimension 101 to 200 are the man hours of outbound calls (y_{tdk}). The dimension 201 to 300 are the man hours of administration tasks (v_{tdk}).

5.2 Computational Results

After using PSO to solve the problem with the numerical example, we turn the results into charts. The Figure 4 is all the test of the best solution. The horizontal axis represents the trials and the vertical axis represents the value of fitness. In the 50 trials, most of the solutions between 30 and 32. The optimal solution is 30 at the 14th test.

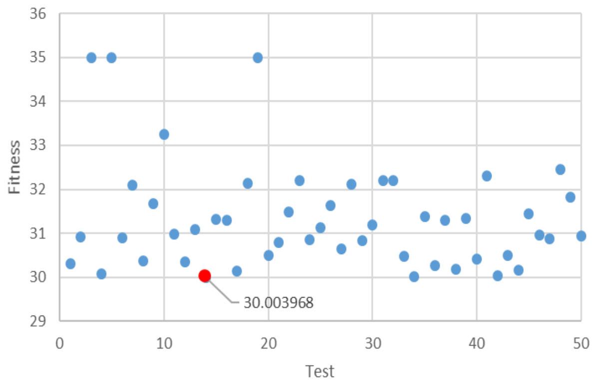

Figure 4: The best solution of every test.

The Figure 5 is the convergence trend at the 14th test. The total iteration of every trial by using PSO is 150000. At the 14th test, the initial solution is 37.9. And about 20000th iterations, the solution converge to 32.2. Finally, the optimal solution 30.

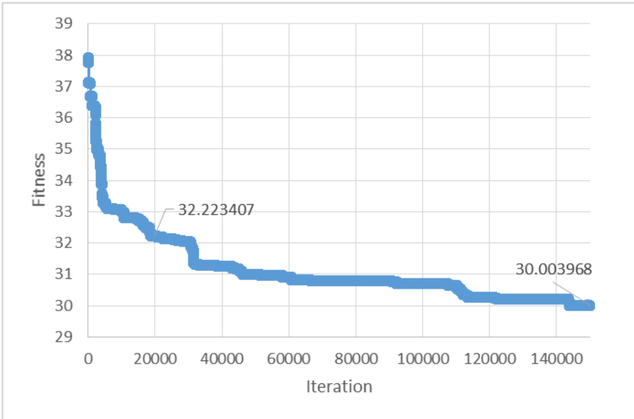

Figure 5: The trend of convergence.

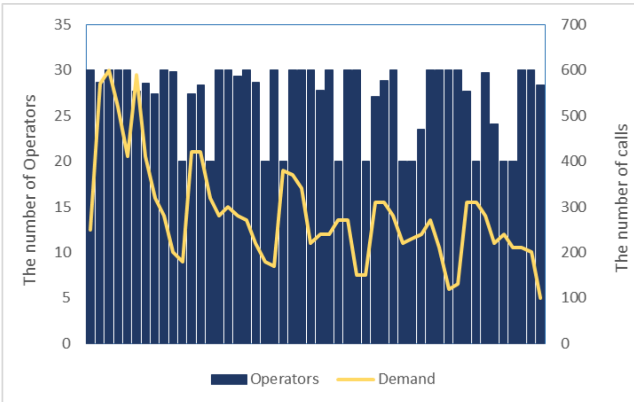

Figure 6: Operators and demand of each time period.

And the Figure 6 is the distribution of operators and demand of each time period. Most of time periods, the optimal staff planning is between 25 and 30. A few of time periods' is 20.

6. CONCLUSION

An advanced assignment program is very important for a hospital call center. Having a good staff planning can make healthcare service more convenient and efficient. In this paper, we formulate a mathematical programming model for the problem by using mixed-integer nonlinear programming. And we use Particle Swarm Optimization (PSO) algorithm to solve the problem. We get the optimal staffing is 30. Compare with (Booranadiloak et al., 2015), this method can significantly reduce the computation time and provide a good allocation of operators for the manager. So, the hospitals can determine the optimal number of operators promptly and offer a good healthcare service.

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