Optimization Approach to Appointment Scheduling

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Abstract

Currently, the intuitive greedy algorithm is generally used for appointment scheduling in health facilities, such as dental clinic. We look into another approach, which is based on statistical data, develop the algorithm, that optimizes the scheduling process, benefiting both the facility and its customers, and then test it on the historical data, using simulation (in progress); positive results of the simulation will indicate that the algorithm is more efficient than the original greedy algorithm, which potentially allows us to implement it in the form of a scheduling software for the variety of health facilities in Canada.

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1 Introduction

1.1 Historical background

Appointment system services are common in modern economies and exist across a wide range of service operations such as health care clinics, law offices, personal care beauty shops, auto repair garages, professional consulting, and many others. Due to rapid growth and development in these industries, there have been excessively high demands for services that were required by clients which supplies, namely service providers, were limited. Then two solutions are suggested: Unreserved appointment system FCFS (First-Come-First-Serve) and reserved appointment system. This paper will only focus on the latter part, i.e. reserved appointment system.

Many studies on appointment scheduling have been conducted since 1950's, with potential for further development. Most of the topics covered on health care clinics, where Bailey (1952) and Welch and Bailey (1952) emphasized the importance of appointment scheduling, as the appointment systems were all unreserved system FCFS in the prior days. The result, indeed, minimized the idle time for the service providers. However, the customers were not satsfied because of the long waiting time in the queue. Soriano (1966) suggested an appointment system having time blocks that would have more than one client booked. This method resulted in the loss of productivity for the service providers.

1.2 Motivation

Currently, when a service provider sets up a reservation, it provides a client with a number of choices for appointment time. The suggested choices are intuitively picked by the experienced receptionist (schedule manager) from the large set of possible appointment times, that are suitable for the client, according to the following logic: if the client needs a service urgently, then a "greedy" approach is used; otherwise, the least demanded time (based on the receptionist's personal experience) is offered.

There are several drawbacks in this logic:

- "human factor", i.e. the possible bias in determining the least demanded time from the receptionist's experience, as well as expected service time;

- the variability in service times needed for each (type of) customer is not considered, which often causes overlapses in the schedule and, therefore, decreases the overall customer satisfaction.

In this paper, we suggest a formal mathematical algorithm, that incorporates both the receptionist's logic and statistical data, and provides the receptionist with the optimal appointment time to suggest to the customer, taking into account both customer satisfaction and business needs.

2 Algorithm

Hard input:

- distribution of customer types (C - set of customer types, $\forall i \in C$ define t_i - probability of a new customer to be of type i) - the distribution will be used solely for simulation purposes;
- distribution of service times for each customer type (assume normality, $\forall i \in C$ define m_i - mean, and σ_i - variance of service time for customer type i);
- distribution of customer time preferences (P - set of possible time preferences, $\forall k \in P$ define p_k - probability of a new customer to have time preference k);
- service provider configuration: business hours, range g within which the regular greedy algorithm is used;
- priority weights (determined by the service provider) $w_h, w_c \geq 0$ for the service provider and the customer priorities, respectively, such that $w_h + w_c = 1$.

Soft input:

- new customer info (customer type $i \in C$, customer time preference $k \in P$ along with the desired time range for the appointment r);
- pre-calulated set T of currently available time slots within the pre-determined overall range, with respect to current schedule and service provider configuration.

Pre-calc:

- pre-calulate set $T^* \subseteq T$ of feasible solutions, by eliminating time slots that do not satisfy the new customer time preference k or the desired time range r;
- define expected "after-appointment" idle time $d(t) : T^* \to \mathbb{R}_+$, where $d(t) = \{$starting time of the next appointment$\}$ - [$\{$starting time of appointment at time slot $t\} + m_i$];
- define $G \subseteq T^* : t \in G \Leftrightarrow \{t$ is within g days$\}$, order elements of G in the increasing order with respect to time;
- $\forall t \in T^*$ define $p(t) : T^* \to P$, where $p(t) = p_k$, if time t is in time preference range k; shift and define the *"demand" rank* $\bar{p}(t)$ in the following way: $\bar{p}(t) = p(t) - p_{min}$, where $p_{min} = \min\limits_{t \in T} p(t)$; also define $\bar{p}_{max} = \max\limits_{t \in T} \bar{p}(t)$.

Algorithm:

IF $G \neq \emptyset$, RETURN $G(0)$, first element of G;

ELSE solve the following optimization problem:

$\mathop{\mathbf{MAX}}\limits_{t \in T} w_h \cdot E_h(t) + w_c \cdot E_c(t)$

Subject to:

- $E_c \in [-1, 1]$ stands for expected "satisfaction" of the next customer (assume that the next customer is satisfied when he most probably does not need to wait, in which case $E_c = 1$, and not satisfied at all if there is a high chance of waiting, in which case $E_c = -1$):

$$E_c = \frac{d(t)}{\sigma_i} - 1$$
$$E_c \leq 1$$

- $E_h \in [-1, 1]$ stands for expected service provider "satisfaction" (assume that the service provider is satisfied, when the appointment is scheduled at the least busy time slot, to leave the time slots with higher demand for succeeding customers, in which case $E_h = 1$, and not satisfied if the appointment is scheduled at the busiest time slot, in which case $E_h = -1$):

$$E_h = -2 \cdot \frac{\bar{p}(t)}{\bar{p}_{max}} + 1$$

RETURN optimal solution;

Output:

- resulting appointment time $t_{res} \in T^*$.

3 Results & conclusion

3.1 Simulation

We are currently in the process of creating a simulation model using Arena Simulation Software along with the third party calendar application to maintain the schedule; the model parameters and statistical data used in the algorithm were obtained from the Simon Fraser Dental Centre, the dental clinic on campus of Simon Fraser University. The model produces the random input (customer type, time preference, time range) for the algorithm and collects the appropriate long-run statistics, such as the idle time for business, while the third party calendar application stores the schedule and keeps track of changes.

Once the results are obtained, they will be compared with the empirical data, that we got from the Dental Centre; the inference on the efficiency of the approach will, then, be made.

3.2 Conclusion

The algorithm, indeed, follows the receptionist's logic. Moreover, it effectively uses the statistical data and methods of Operations Research to avoid the drawbacks of the original approach, and provides the receptionist (schedule manager) with the optimal appointment time to suggest to the customer, based on the quantitative evidence.

This approach is very flexible and, therefore, can be applied broadly and adjusted to one's convinience, as the choice of model parameters sets business priorities. The (statistical) data is quite simple to get, and the algorithm generally works fast, except the extreme cases, when number of feasible solutions is too big due to high discretization.

3.3 Possible improvements

The more complex service configuration is one way for improvement. The advanced model can potentially include multiple service ”stations” of different type (e.g. dental doctors and hygienists) and different service times(e.g. different skill levels). Another possibility is to improve the ”after-greedy” part of the algorithm by incorporating the distribution of customer types in the demand ”rank”.

References

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