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Psychological Acceptability Weighted Priority Scheduling: A Case Study of Animal Hospital

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Abstract: A solution to the patient scheduling problem for a case study animal hospital called Mix+Factor scheduling is proposed in this work. Mix scheduling is based on the weighted sum of patient arrival order, the job type and the priority. The priority is based on the veterinarian opinion on the treatment type. Factor is an additional function based on the psychological acceptability of the patient owners in allowing some later jobs to be moved ahead in the waiting queue. The experimental results are conducted on three synthesis workloads to create a light-load, normal-load and high-load conditions. The synthesis workloads are created according to the mixture of jobs at the case study animal hospital. The results show that the Mix+Factor algorithm provides similar or better average waiting time performance in comparison with the currently used algorithms, namely First-Come-First-Served. In addition, Mix+Factor can also provide a better scheduling in order to reduce the waiting time for specific patients such as violence animals or patients with appointments. A study on potential benefit of opening an extra treatment room shows that an extra treatment room can significantly reduce the waiting time and better serve the specific patients than that of the currently used algorithm.

Keywords: Weighted Sum, Scheduling, Non-Preemptive

Introduction

Many families consider pets such as cats or dogs as their family members. As a result, the number of animal hospital has increased. The animal health care services include preventive activities such as vaccination and treatment activities. In fact, the owner of the patients (animals) expect to receive a quality service and a fast service. In addition, some patients can be difficult to control even by their owner and the patients can be violent toward others. With some illness, the violation of the patients can be amplified. As a result, the stressed level of the patients' owners can be affected.

Previous literatures focus on solving the hospital planning and scheduling problems (Hulshof *et al*., 2012; Javid *et al*., 2017; Zhu *et al*., 2010), (Srinivas and Ravindran, 2018). However, these scheduling algorithms are focusing on providing a general solution for efficiency. Hulshof *et al*. (2012) presented the structured overview of the decisions for planning in six health care services; ambulatory, emergency, surgical, inpatient, residential and homecare care services. Their planning consists of strategic planning, tactical planning and operational planning (both offline and online). It only reviews the key in each services for decision making. Srinivas and Ravindran (2018) proposed a prescriptive analytics framework to improve the performance of appointment system. This system used for outpatient clinics the measurements include average patient waiting time, number of patients unable to get an appointment for the day under consideration, average resource idle time, overflow time and overtime. This framework consisted of three steps; collect the patient data, machine learning (i.e., logistic regression, artificial neural network). The results indicated that the proposed scheduling rules consistently outperformed the benchmark rules for all the clinic settings tested. Zhu *et al*. (2010) proposed the factors causing long patient waiting time and clinic overtime in outpatient clinics, overloaded session, late start of a session and unused session time and how to mitigate them using a discrete event simulation. It collected the data from three categories of information; appointment type, detailed timings and staff remarks.

The scheduling of patients in the animal hospital can be classified as a multi-objective optimization problem because there are many factors to be considered such as the arrival time of the patients, the type of treatments and the room availability.

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Since a weighted sum priority function is a common concept in solving multi-objective optimization problems (Marler and Arora, 2010), in this work we proposed some weighted sum priority scheduling algorithm. The set of weights used by the priority scheduling algorithms are generated according to the patient's owner opinions in order to reflect the psychological acceptability of the patient's owner in the scheduling results.

The case study animal hospital is a small facility in Phuket province, Thailand. This animal hospital opens only one treatment room with a lot of patients. Therefore, the hospital is always clouded with patients and their owners. The waiting time for services is also long. The current scheduling at the case study animal hospital is First-Come-First-Serve (FCFS) meaning the patient will be serviced in the order of their arrivals. As a result, the waiting time of some patients are long even though the patients require only a short service time. Such event can cause some unfairness from the patients' owner point of view. Moreover, the patients might pick a fight with each other because some patients could be very violent by nature.

Thus, this work aims to investigate several other scheduling algorithms to reduce the effects of a long waiting time. In addition, there are extra treatment rooms and there are several veterinarians. Therefore, the hospital can open more than one treatment room for the patients if needed. Thus, this work also aims to show the potential benefit of opening an extra treatment room for the hospital consideration.

Methodology

The methodology consists of four parts. First part is the survey. The survey is conducted on both the patient's owner and the veterinarian to acquire the required information for our proposed solution. The patient's owner can provide the level of psychological acceptability to be used in our proposed scheduling algorithm. While, the type of treatment and the treatment time of each treatment type can be used to generate the workloads for evaluating our proposed solution. Moreover, the current scheduling algorithm used by the hospital will be used as the baseline for our experiments.

Second, an off-line experiment is conducted to evaluate our proposed scheduling algorithm against several baseline algorithms. The off-line experimental results will help to evaluate the potential performance of the proposed scheduling since all job arrival times are known to the scheduler. The scheduler has a full picture of the workload at the scheduling point. However, the off-line experiment is not realistic.

Third, an on-line experiment is conducted to evaluate our proposed scheduling algorithm and the baseline algorithms in a more realistic situation. Under an on-line experimental setting, all job arrival times are not known to the scheduler. Thus, the scheduler must schedule each job without the knowledge of what job will arrive next. This setting is more realistic. Also, the effect of the realistic situation can be compared with the performance of the ideal situation (off-line) in order to show the full potential performance of the proposed algorithm.

Forth, an experimental result of operating an extra treatment room is conducted in order to show the effect of adding an extra treatment room on the patient's waiting time.

Survey Results

To propose a suitable scheduling algorithm to the case study animal hospital, a survey on fifteen patient's owners and the on-site veterinarian is conducted. The veterinarian survey questions focus on the treatment time of the patients. According to the survey results with the on-site veterinarian, the treatment can be classified into five types including 'Emergency', 'Special', 'General', 'Vaccination' and 'Parasite and flea'. Emergency case has the highest priority because some emergency cases must be handled quickly. Special case referring to a difficult case or a rare case, is given the second highest priority. General case is the most common case occurred which is given the next priority on the list. Vaccination case and Parasite and flea case are given equal priority because both jobs are short.

The patient's owner survey questions focus on the psychological acceptability of the patient's owner in accepting the actions of moving some later jobs ahead in the waiting queue. Out of all factors on the survey questions, the factors that at least 80% of the patient's owner do not accept, are cut. Therefore, only five factors are acceptable by the patient's owners to be a reasonable cause of moving some later jobs ahead in the waiting queue. The five factors from the highest acceptable score to the lowest acceptable score include 'Appointment', 'Violence of Animals', 'Sensitivity of the owner', 'Conditions of the owner' and 'Members'. Appointment means that the patient already had an appointment to see the veterinarian and they arrive at the facility on the time of their appointment even though there are patients waiting in the queue, the appointment must be respect. Violence of Animals refers to the type of animals that needs the treatment. For example, British Bulldog or Rottweiler could possibly harm other animals if they are kept waiting in the queue. Sensitivity of the owner refers to some harmful people that can create a scene and annoy others. Conditions of the owner refers to a special condition of the owner such as pregnancy. Thus, the condition of the patient's owner must be the cause of acceptability of moving the patient ahead in the waiting queue. The last factor is member meaning if the patient is the member of the institute, the patient must be allowed to have an extra privilege.

Proposed Scheduling Algorithm

The proposed scheduling algorithm in this work is called Mix+Factor scheduling. Mix+Factor scheduling is a combination of Mix scheduling and Factor each of which is described below.

Mix scheduling uses the priority function given in (1) to order the patients in the waiting queue. Mix scheduling is designed to balance the influent of First-Come-First-Serve (fcfs), Shortest-Job-First (sjf) and the priority by mixing them together. First-Come-First-Seve values the order of patient arrival time while Shortest-Job-First values the short treatment time.

According to (1), fcfs and sjf is transformed into a priority value between zero and one according to (2) and (3), respectively. According to (2), the first job will have the highest fcfs priority of 1; the second job will have the fcfs priority of 0.98; the last jobs will have the fcfs priority of 0.02 if there are 50 jobs in the workload. According to (3), the smallest job size (i.e., 10-minute job) will have the sjf priority of 0.98; the largest job size will have the sjf priority of 0.25 if the largest job size is 360 minutes or 6 hours. The value 480 minutes is used as the normalization because the case study animal hospital open business hour at 8 hours per day.

In this work, the priority is given to each job according to the job type which is the result of the survey presented previously. To normalize the priority to the range of zero to one, each of the five job types including emergency, special, general, vaccination, parasite and flea, is given the priority value as 1, 0.8, 0.6, 0.4 and 0.4, respectively.

Factor is calculated according to the survey result. From the survey results, we can normalize all five factors to have its value between zero and one as follow. Appointment has a value of 1; Violence of Animals has a value of 0.6; Sensitivity of the owner has a value of 0.4; Conditions of the owner has a value of 0.4; Member has a value of 0.33:

$$Mix\ priority = fcfs + job\ type + sjf \quad (1)$$

$$\begin{aligned} fcfs &= 1\ if\ it\ is\ the\ first\ job \\ &= 1 - \left(\left(job\_order\right) - 1\right) / total\,\#\,jobs\ otherwise \end{aligned} \quad (2)$$

$$sjf = 1 - \left(job\_service\_time\ /\ 480\right) \quad (3)$$

Experimental Settings

Algorithms

Six scheduling algorithms are evaluated in this work. The algorithms include First-Come-First-Serve (FCFS), Shortest-Job-First (SJF), Priority, Priority+Factor, Mix and Mix+Factor. FCFS, SJF and Priority scheduling algorithm are used as the baseline algorithm since each of which has its advantage. Mix and Mix+Factor scheduling algorithms are explained in the previous section.

First-Come-First-Serve (FCFS) gives the highest priority to the oldest job. FCFS will be used as the baseline performance because it is the current scheduling algorithm at the case study animal hospital. The best known disadvantage of FCFS is the large average waiting time (Zhou and Garg, 2015). The new arriving job will be inserted into the back of the queue and the job at the head of the queue will be scheduled first (Abraham *et al*., 2012).

Shortest-Job-First (SJF) gives the highest priority to the short jobs (Farooq *et al*., 2017). In this experiment, the SJF is non-preemptive meaning the executing job will not be stopped. The best known advantage of SJF is the lowest average waiting time by allowing the large jobs to suffer.

Priority scheduling gives the highest priority job to be scheduled first. Recall the priority of each job type as described in the previous section as follow: Emergency, Special, General, Vaccination, Parasite and flea is given the priority value as 1, 0.8, 0.6, 0.4 and 0.4, respectively. The main disadvantage of a priority scheduling is the low priority job can be starved (Hasija *et al*., 2013). Factor as described in the previous section is combined with priority scheduling to create Priority+Factor scheduling.

Workloads

All experiments, in this work, are conducted using three synthesis workloads called DT1, DT2 and DT3 shown in Table 1. There are 50 jobs in each data set. Each of which consists of 5 types of jobs including parasite and flea, vaccination, general, special and emergency cases. In this work, each patient requires only one type of treatment. Thus, any successive case is not covered in this work.

Table 1: Workload characteristics

	Total Service Times (hrs)		
Job types	DT1	DT2	DT3
Parasite and flea	1.67	3.67	0.83
Vaccination	2.50	4.50	1.25
General	12.00	4.50	11.50
Special	12.50	5.00	15.50
Emergency	27.50	7.00	62.50
Total	56.17	24.67	91.58
Number of jobs			
Parasite and flea	10.00	22.00	5.00
Vaccination	10.00	18.00	5.00
General	10.00	3.00	11.00
Special	10.00	3.00	14.00
Emergency	10.00	4.00	15.00
Total	50.00	50.00	50.00

The service time of each job type is collected from an interview with the staff at the case-study institute. The workloads are generated in order to create three situations including a normal (DT1), a light (DT2) and a high (DT3) load. DT1 has equal number of jobs in each type. DT2 has 80% of parasite and flea and vaccination jobs. The service times of these two job types are 10 and 15 min, respectively. DT3 has 80% of general, special and emergency jobs which have a service time of 30 min or more. The longest service time belongs to emergency jobs which can be as long as 6 h.

Experimental Results

Three sets of experiments are conducted in this work to evaluate the potential of the proposed scheduling algorithm including the off-line performance evaluation, the on-line performance evaluation and the effect of an extra treatment room.

Off-Line Performance

To study the effect of each algorithm, the experiments in this section are conducted offline. Thus, all jobs are arrived at the same time with a correct service time information. Table 2 shows the average waiting time performance of all six scheduling algorithms on DT1, DT2 and DT3. The number of jobs completed within the first 8 hours of each data set of each scheduling algorithm is presented in Table 3. As expected, the average waiting time of DT2 on all jobs of each algorithm is lower than its counterpart of DT1 and DT3 because the total service time of DT2 is the smallest (24.67h) among all three workloads. Also, the average waiting time of DT3 on all jobs of each algorithm is higher than its counterpart of DT1 and DT2 because the total service time of DT3 is the largest (91.58h) of three workloads.

On the performance of each algorithm, the SJF provides the lowest average waiting time of all jobs among 6 algorithms on all three workloads which is expected. In comparison with the baseline performance (FCFS performance), the SJF provides a better average waiting time performance of all jobs among 6 algorithms by suffering the emergency jobs (i.e., long jobs). The average waiting time of emergency jobs provided by SJF for DT1, DT2 and DT3 is 28.22h, 16.17h and 50.52h, respectively. The average waiting time of emergency jobs provide by FCFS for DT1, DT2 and DT3 is 27.24h, 8.75h and 42.11h, respectively.

Table 2: Average waiting time performance

	FCFS			SJF		
Job Types	DT1	DT2	DT3	DT1	DT2	DT3
Parasite and flea	31.83	12.07	33.88	0.75	1.75	0.33
Vaccination	23.39	10.56	28.57	2.79	5.79	1.33
General	33.98	11.14	46.86	15.57	11.17	12.17
Special	24.56	18.28	44.83	14.47	17.50	11.69
Emergency	27.24	8.75	42.11	28.22	16.17	50.52
Total	28.20	11.58	41.74	12.36	5.87	21.27
Job Types	Priority			Priority + Factor		
Parasite and flea	54.33	20.89	90.68	32.38	15.68	57.38
Vaccination	53.74	20.14	90.27	37.44	16.50	78.67
General	44.60	13.50	82.32	37.00	8.83	59.26
Special	33.95	8.50	70.46	26.05	11.69	36.79
Emergency	13.00	2.88	28.00	25.58	8.81	38.21
Total	39.92	17.98	64.34	31.69	14.78	48.41
Job Types	Mix			Mix + Factor		
Parasite and flea	37.98	15.48	42.58	27.98	14.76	35.73
Vaccination	30.64	13.17	33.57	29.16	15.21	55.60
General	34.56	12.42	45.58	33.95	9.33	47.70
Special	19.87	16.72	29.74	23.16	13.97	28.65
Emergency	22.46	5.17	40.62	25.79	8.77	40.79
Total	29.10	13.71	38.15	28.01	14.07	39.89

Table 3: Number of jobs finished within the first 8 h

	FCFS			Priority		
Job types	DT1	DT2	DT3	DT1	DT2	DT3
Parasite and flea	0	6	0	0	0	0
Vaccination	3	7	1	0	0	0
General	0	0	1	0	0	0
Special	1	0	1	0	0	0
Emergency	2	2	1	2	4	3
Total	6	15	4	2	4	3

Interestingly, the average waiting time of all jobs provided by the Priority+Factor outperform that of the Priority on all three data sets. By adding Factor to the Priority, the priority of some emergency jobs will be reduced in order to make ways to other job types. As a result, the overall performance of the whole data set is reduced. With all jobs arriving at the same time, all jobs must wait for the starting job to finish before one of them can start. Thus, all jobs must wait for the total service time of all previously starting jobs. One finding from this result is that the emergency jobs may need a special attention in order to reduce the waiting time of other job types. A solution to such issue could be an additional treatment room for an emergency case. This way, the emergency jobs will not significantly disturb the remaining jobs.

Another interesting finding is the overall average waiting time performance of Mix which is very similar to that of FCFS on all three data sets. This can be concluded that Mix priority is significantly influenced by the order of the jobs. Unlike the significant influent of Factor on the performance under Priority, the Mix+Factor performance can only clearly outperform Mix performance on the average waiting time of one particular job type (i.e., parasite and flea job type) on all three workloads. The parasite and flea jobs are the smallest job size in all workloads. For other job types, the performance of both algorithms is very similar.

To analyze the influent of Factor, Table 4 shows the waiting time of the jobs without any additional factor under Mix, Mix+Factor, Priority and Priority+Factor of all three data sets. There are 7 jobs out of three data sets without any additional factor meaning the job priority seen by the scheduler under all algorithms are the same. However, Mix+Factor and Priority+Factor will see additional priority on other jobs in the workloads. Thus, the other jobs besides these 7 jobs will have different priority values among these 4 algorithms. The waiting time performances of these 7 jobs when Factor is added are all increased which is expected. Therefore, the additional factor does have an influent on the resulting schedule.

On-Line Performance

To simulate the real scenario, each job in the workload in this experiment is assigned an arrival time. The arrival time of the jobs follows a Poisson distribution with the average of 6.67 person/hour, resulting from the observation results during the busy hour of service. Since the weighting of the priority function will affect the resulting schedule, the online experiments that each job may arrive at a different time must also be studied.

Table 5 shows the average waiting time performance of FCFS and Mix+Factor algorithms when conducting an online version of the experiments. Mix+Factor provides a better overall performance on heavy load while both algorithms provide similar performance on the other two workloads. For the detail analysis of the performance, Mix+Factor provides a better or similar performance on most job types except Vaccination in comparison with that of FCFS for normal load. For the light and heavy load, Mix+Factor scheduling outperforms FCFS in all job types except Vaccination.

For the detail performance, Mix+Factor can fasten the waiting time for the violence animal in all cases. Table 6 shows the average waiting time of the violence patients. For normal workload, the waiting time of the violence animal is 39.83hr for FCFS and 38.42hr for Mix+Factor. For light workload, the waiting time of the violence animal is 16.20hr for FCFS and 5.7hr for Mix+Factor. For heavy workload, waiting time of the violence animal is 71.35hr for FCFS and 20.10hr for Mix+Factor. Thus, Mix+Factor can fasten the waiting time such that the violence animal will remain in the hospital for less than that of the current situation that uses FCFS.

Table 4: The waiting time of the jobs without any additional factor

		Waiting time (hrs)	
Data set	Job no: Job type	Priority	Priority + Factor
DT1	4: special	27.50	52.08
	28: general	54.33	56.00
	49: parasite and flea	50.00	54.00
DT2	21: vaccination	19.92	24.25
	37: parasite and flea	22.67	24.50
DT3	3: emergency	0.00	85.67
	37: general	83.50	90.58
		Mix	Mix + Factor
DT1	4: special	1.00	46.08
	28: general	39.83	54.00
	49: parasite and flea	48.67	54.17
DT2	21: vaccination	11.92	24.25
	37: parasite and flea	22.67	24.50
DT3	3: emergency	0.00	65.33
	37: general	57.17	90.58

Table 5: Average waiting time performance online version

Job Types	FCFS			Mix + Factor		
	DT1	DT2	DT3	DT1	DT2	DT3
Parasite and flea	27.62	8.51	30.93	24.22	3.72	33.33
Vaccination	20.30	7.47	26.29	26.07	11.31	32.73
General	29.44	7.73	42.90	29.41	2.53	42.56
Special	21.37	12.49	41.04	21.77	3.29	24.38
Emergency	23.44	5.84	38.35	22.12	0.37	37.77
Total	24.44	3.25	38.16	24.72	3.43	34.13

Table 6: Average waiting time performance (violence)

FCFS			Mix + Factor		
DT1	DT2	DT3	DT1	DT2	DT3
39.83	16.20	71.35	38.42	5.70	20.10

Moreover, the patients with appointments also benefit from the Mix+Factor algorithm over the currently using FCFS algorithm. Table 7 shows the average waiting time of the patients with appointments. According to the results shown in Table 7, Mix+Factor significantly reduces the average waiting time of the patients with appointments in comparison with the currently used scheduling algorithm. For normal workload, the waiting time of the patient with appointment is 28.73hr for FCFS and 14.58hr for Mix+Factor. For light workload, the waiting time of the patient with appointment is 12.52hr for FCFS and 10.05hr for Mix+Factor. For heavy workload, waiting time of the patient with appointment is 46.32hr for FCFS and 37.36hr for Mix+Factor.

Effect of an Extra Treatment Room

Moreover, the animal hospital may consider open an extra treatment room for a better service to either handle the emergency jobs or the short jobs. Thus, the experiments in this section are conducted by assuming that there is an extra treatment room in order to evaluate the performance of Mix+Factor algorithm in comparison with FCFS. Each job in the workload in this experiment is assigned an arrival time. The arrival time of the jobs follows a Poisson distribution with the average of 6.67 person/hour, resulting from the observation results during the busy hour of service.

However, there are two variations in assigning the extra treatment room. First case, the extra room will be reserved for only Emergency cases while the other case the extra room will be assigned to the Emergency patient if there exists. However, if there is no Emergency patient and there is a waiting patient then the extra room will be assigned to the waiting patient. Table 8 shows the results of the first case while Table 9 shows the results of the second case.

According to the results shown in Table 8, Mix+Factor provides a better overall average waiting time performance in normal and heavy workloads (DT1 and DT3) while it provides a slightly worst performance on the light workload (DT2). Similar trend can be observed from the results in Table 9. That is, Mix+Factor provides a better overall average waiting time performance on heavy workloads (DT3) while the performance is similar in normal and light workloads (DT1 and DT2). One significate finding is that two treatment room performance is better than that of using one treatment room regardless of the room assignment policy. The better policy for the extra room assignment for an extra treatment room is to assign the Emergency case into the room first if one does exist. Otherwise, the room should be assigned to the waiting patient to better utilize the room.

Further analyze the performance of the patient with violence animal is shown in Table 10. Two treatment rooms can significantly reduce the waiting time as expected. Mix+Factor outperforms FCFS in both room assignment cases. For this set of workloads, Mix+Factor scheduling algorithm with the room assignment Case 2 seems to favor the patient with violence animal than Case 1. According to the results presented in Table 10, the average waiting time performance of violence animals when using Mix+Factor with case 2 room assignment is 2.92hr, 0.62hr and 6.50hr for normal, light and heavy load, respectively. While, the average waiting time performance of violence animals when using Mix+Factor with case 1 room assignment is 7.08hr, 1.98hr and 7.48hr for normal, light and heavy load, respectively.

The performance of the patients with appointments shows in Table 11. Two treatment rooms can significantly reduce the waiting time as expected. Mix+Factor outperforms FCFS in both room assignment cases. For the normal workload, the room assignment Case 2 outperforms the room assignment Case 1 significantly. That is, the average waiting time of the patient with appointment of Mix+Factor with case 1 room assignment is 6.35hr while it is 11.63hr for case 2 room assignment.

Table 7: Average waiting time performance (appointment)

FCFS			Mix + Factor		
DT1	DT2	DT3	DT1	DT2	DT3
28.73	12.52	46.32	14.58	10.05	37.36

Table 8: Average waiting time performance (case 1)

	FCFS			Mix + Factor		
Job Types	DT1	DT2	DT3	DT1	DT2	DT3
Parasite and flea	12.04	2.95	13.48	13.55	3.85	21.11
Vaccination	3.74	0.76	15.25	6.48	0.33	14.16
General	12.64	5.02	20.61	10.24	3.23	13.70
Special	16.49	3.46	21.98	14.19	2.58	20.98
Emergency	16.75	3.67	17.62	11.80	3.79	18.55
Total	12.33	3.25	18.29	11.25	3.43	16.67

Table 9: Average waiting time performance (case 2)

	FCFS			Mix + Factor		
Job Types	DT1	DT2	DT3	DT1	DT2	DT3
Parasite and flea	8.02	2.23	11.09	10.97	3.85	20.31
Vaccination	9.40	1.62	16.94	8.17	0.37	15.15
General	8.15	3.59	18.15	8.76	3.29	10.67
Special	11.87	2.53	18.44	11.69	2.53	19.22
Emergency	11.30	3.72	13.36	9.63	3.72	15.31
Total	9.75	3.25	18.29	9.85	3.43	16.67

Table 10: Average waiting time performance (violence)

	FCFS			Mix + Factor		
Room assignments	DT1	DT2	DT3	DT1	DT2	DT3
One room	39.83	16.20	71.35	38.42	5.70	20.10
Case 1	14.83	6.07	28.48	7.08	1.98	7.48
Case 2	16.42	4.62	32.57	2.92	0.62	6.50

Table 11: Average waiting time performance (appointment)

	FCFS			Mix + Factor		
Room assignments	DT1	DT2	DT3	DT1	DT2	DT3
One room	28.73	12.52	46.32	14.58	10.05	37.36
Case 1	11.76	4.37	20.30	11.63	3.12	16.62
Case 2	12.00	4.37	21.81	6.39	4.36	19.05

However, the Mix+Factor with case 2 room assignment provides a slightly worst performance on light and heavy workloads. That is, the average waiting time of the patient with appointment of Mix+Factor with case 1 room assignment is 3.12 and 16.62 for light and heavy load, respectively. While, the average waiting time for the patient with appointment of Mix+Factor with case 2 room assignment is 4.36hr and 19.05hr for light and heavy load, respectively.

Conclusion

Mix+Factor scheduling algorithm is proposed in this work to schedule the patients at a case-study animal hospital in Phuket, Thailand. Mix is designed to balance the influent of FCFS, SJF and the priority by mixing them together. The priority is given to each job according to the job type which is the result of the survey on the veterinarian. Factor is an influent of the psychological acceptability of the patient's owner according to the survey results. Currently, the case-study institute uses FCFS as the main scheduling algorithm.

The experiments in this work were conducted on three synthesis workloads, each of which consist of five jobs types. The mixture of the job types are generated according to the staff interview results in order to create a normal, a light and a high workload. Six algorithms used in this work include

FCFS, SJF, Priority, Priority+Factor, Mix and Mix+Factor. The FCFS is used as the baseline because it is the currently used algorithm at the case study institute. The SJF gives the high priority to the short job. The Priority gives the priority according to the treatment type. The Mix is a combination of FCFS, SJF and Priority. The Mix + Factor uses the Mix priority with an additional priority value according to psychological acceptability of the patient's owner in allowing some later patients to be moved ahead in the waiting queue. Priority + Factor uses the Priority with an additional priority value according to the patient's owner survey results as well.

The experimental results on ideal off-line situation to study the potential of each algorithm show that Priority alone cannot outperform the FCFS performance. However, the average waiting time on the emergency jobs is better than that of the FCFS. Factor does have an influent on the resulting schedule and the influence is significant under the Priority. Mix+Factor provides the best average waiting time on all job types for the normal load and the best overall average waiting time for high load. While, the performance of all algorithms is similar for the light load.

The experimental results on an online setting which is similar to a real situation show that Mix+Factor provides a better overall performance on heavy load while both algorithms provide similar performance on the other two workloads. However, the detail analysis on the results show that Mix+Factor can reduce the waiting time of the violence animal on all workloads in comparison with that of the currently used algorithm (FCFS). In addition, the Mix+Factor can also reduce the waiting time of the patient with appointment on all workloads in comparison with the currently used scheduling algorithm (FCFS).

In addition to the proposed algorithm (Mix+Factor) to re-order the patient according to the psychological acceptability of the patients as shown above, this work also studies the benefit of adding an extra treatment room. By addition an extra treatment room, the waiting time of all patients are significantly reduced which is expected. For the performance of Mix+Factor algorithm in comparison with that of the currently used algorithm, the Mix+Factor algorithm provide a better overall average waiting time in all cases. However, an extra treatment room can also be utilized for the currently waiting patients as well.

Our future works include an economic analysis of the extra treatment room and hour of operations. An extra treatment room can incur some cost associated with it and the patients may not be filled in all hours of operations. Thus, the extra treatment room may be able to have a different hour. This way, the hospital will not have to increase a lot of cost for an extra treatment room in all hours. Therefore, a suitable operation hour for the extra treatment room must be studied.

Since this work assumes that each patient requires only one type of treatment, our future work is to study the impact of successive care when the patient can have many treatments in one visit.

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Author's Contributions

Kitsiri Chochiang: Designing the research, conducting the data analysis, concluding the research results, providing the conclusion and suggestion, writing the manuscript, conducting the review of the manuscript, revising the manuscript, contacting the editorial office.

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Vachira Masosot: Conducting the experiments.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all the authors have read and approved the manuscript and there are no ethical issues involved.

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