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Closed Self-Help Sharing Printing Model for Library Service Improvement

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***Abstract*—In order to solve the problems in the construction of smart library, such as the delay of the request response of the self-service printing system, the long queuing time of users and the low efficiency of the printer, taking Shanghai University of Medicine & Health Sciences as an example, a scientific and reasonable service model scheme was developed to improve the efficiency of printers and service satisfaction. The applicable queuing model was determined according to the actual printing demand characteristics, then sample and calculate the background initial data, mine the required key parameters, and calculate the relevant operational indicators. After operation and analysis, the optimal solution results under different parameters were compared, and the most practical service model was proposed.**

***Keywords*—Intelligent Library, Sharing Printing Service, Closed Type**

I. INTRODUCTION

With the deepening of the construction of smart libraries, more and more intelligent interactive devices are gradually being applied to various scenes of the library[1-3]. Self-service shared printers are such devices which are favored by teachers and students. Self-service shared printer system is generally a closed system consisting of c printers and n input terminals (n>c). Due to price and other factors, the number of printers cannot be increased arbitrarily, but the input terminal equipment can be supplemented appropriately. Therefore, the following problems are often encountered during use, such as: 1) The actual utilization rate evaluation method of the printer is insufficient to deeply tap the potential, which is easy to cause resource waste or shortage; 2) Users in peak period reflect long waiting time in queue; 3) It takes a long time to wait for a print request response at peak times. For the solution of the above problems, it is necessary to scientifically and rationally optimize the combination, and also fully consider the economic factors.

Queuing theory at home and abroad has done a lot of study on computer networks, software reliability, transportation, social services, etc[4-8]. The library's research in the service desk and circulation services is also constantly achieving new results[9-11]. The standard form of the queuing model is X/Y/Z/A/B/C[12], where X represents the distribution of successive arrival intervals, Y represents the distribution of service time, Z represents the number of service desks, A represents the capacity limit of the system, B represents the number of readers and C represents the service rules.

According to the configuration of the existing self-service printing system in the library of Shanghai University of Medicine &Health Sciences, combined with the queuing related model and operational indicators, this study reasonably mines the background data information, accurately calculates the relevant parameters, and determines the optimal combination.

II. PRINTER SERVICE SYSTEM

A. Shared print service model

The self-service Shared printing system studied in this paper is to connect several Shared printers and input terminals within the designated local area network. The arrival of the user is in accordance with the Poisson flow[13-14]. User arrival interval and print service time are subject to negative exponential distribution. The most striking feature is the closure, which is embodied as follows:1) The number of printers and input terminals in the system are closed, and requests from other terminals are not accepted; 2) As the input terminal of limited source, the actual arrival rate T is the average number of service requests per input terminal per unit time, rather than the total number of users of the system. Because the user comes to the system in a unit time, the attributes of each input are the same, and the random selection probability is the same. The average number of requests is consistent for each input terminal, while the number of requests received by the system in unit time is the real "queuing user". In fact, a closed printing system with multiple input devices, whether printing or copying requests, returns to the original system after completing the service and waits for the next service request, and so on. In this state, the system operation process conforms to the situation shown in figure 1.

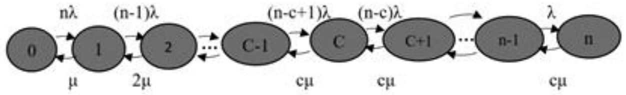

Fig. 1. M/M/c/n/n operation flow chart

This figure is the closed print service model M/M/c/n/n that is mainly studied in this paper. The specific meanings of the parameters are as follows.

1. There are c self-service shared printers in the system, and the system capacity and input number are both fixed n.
2. Each input request rate is λ and the system average service rate is μ.

B. *Operational indicator*

From Figure 2, we can derive the K-algebraic equations for system equilibrium.

State 0 (that is, the printer is idle), $n\lambda P_0 = \mu P_1$ ，$P_1 = \frac{n\lambda}{\mu} P_0 = \rho_1 n P_0$.

Status 1 (that is, 1 printer response work), $\lambda P_1 = 2\mu P_2$ ，$P_2 = \frac{(n-1)n}{2!} P_0 \rho_1{}^2$.

C-1 printer response, $(n-c+1)\lambda P_{c-1} = c\mu P_c$ ，$P_c = C_n^c P_0 \rho_1{}^c$.

C printer response, $(n-c)\lambda P_c = n\mu P_{c+1}$ ，$P_{c+1} = \frac{n(n-1)\ldots(n-c)}{c!c} P_0 \rho_1{}^{c+1}$.

The response probability of exceeding c but not exceeding n is:

$$P_{c+k} = \frac{n(n-1)\ldots(n-c-k+1)}{c!c} P_0 \rho_1{}^{c+k} \quad (1 \leqslant k \leqslant n) \qquad (1)$$

$$P_d = \begin{cases} C_n^d P_0 \rho_1{}^d ，当\ 0 \le d \le c\text{-}1 ， \\ \frac{C_n^d d!\rho_1{}^d}{c!c^{d-c}} P_0 ，当\ c \le d \le n. \end{cases} \qquad (2)$$

$$P_0 = \left(\sum_{d=0}^{c-1} C_n^d \rho_1{}^d + \sum_{d=c}^{n} \frac{C_n^d d!\rho_1{}^d}{c!c^{d-c}} \right)^{-1} \qquad (3)$$

$$L_q = \sum_{d=c+1}^{n} (d-c) \frac{C_n^d d!\rho_1{}^d}{c!c^{d-c}} P_0 \qquad (4)$$

$$L_s = L_q + \frac{\lambda_e}{\mu} \qquad (5)$$

L_q is the average queue length and L_s is the overall average queue length of the system. Among them, $\lambda_e = \lambda(c - L_s)$. As we can see from the actual situation, there will be some input correct waiting for the printer response in unit time, only $c - L_s$ input terminals can be used, that is to say, the actual number of requests printed per unit time is not λ, but λ_e.

$$P_e = \frac{L_s - L_q}{c} \qquad (6)$$

$$W_q = \frac{L_q}{\lambda_e} \qquad (7)$$

$$W_s = \frac{L_s}{\lambda_e} \qquad (8)$$

P_e is the actual use efficiency of the printer, W_q is the response time waiting for the print request, and W_s is the average print time of the staying system.

III. SELF-SERVICE SHARED PRINT SERVICE MODEL

A. *λ estimation*

For the number of print requests λ issued by each input terminal per unit time, it is necessary to calculate the average number of users in the unit time, namely, λ_T to determine. λ_T can be obtained by data mining statistical analysis based on the data recorded in the background of the access control system. Here, SPSS Modeler and other related software are used for modeling, as shown in figure 2 below.

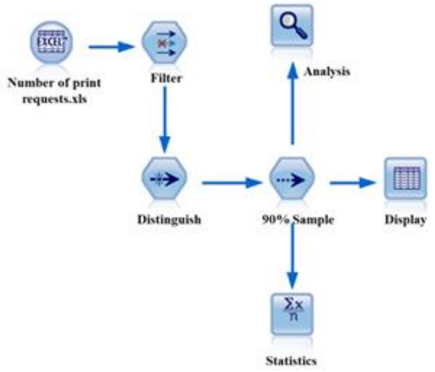

Fig. 2. Statistical analysis of data mining

Therefore, the stratified sampling value of the daily printing time period is required. The 180-day sample was selected from the sample population of the 200-day print request, and the data was randomly selected for 10 days to calculate the relevant unbiased estimates, as shown in Table 1[15].

Tab.1 Request for printer service number sampling

Layer（*h*）	Randomly selected for 10 days									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
h1(8：00-10：30)	44	55	62	46	39	52	56	35	25	39
h2(10：30-12：30)	76	87	96	105	112	83	51	77	98	83
h3(12：30-14：30）	118	123	147	153	119	109	68	85	91	67
h4(14：30-16：30)	44	56	31	65	74	78	83	99	45	31

According to the stratified sampling correlation theorem, the above data can obtain an appropriate estimated value $\widehat{\overline{Y}_h}$ of each layer mean $\overline{Y}$, layer weight W_h, sampling ratio f_h, sample variance of each layer S_h^2, 95% confidence interval of λ_T, etc.

$\hat{\bar{Y}}_{st}$ is the unbiased estimate of $\widehat{\bar{Y}}_h$, the simple estimate of total Y is $\hat{Y}_{st}$ =N $\bar{y}_{st}$, $\hat{v}$ （$\hat{Y}_{st}$） is the variance unbiased estimate of $\hat{Y}_{st}$.

Table.2 Request printer service statistics

h	**N*h***	**n*h***	***fh***	***wh***	**Minimummum**	**Maximummum**	**Mean** ($\bar{y}_h$)	**N*h*$\bar{y}_h$**	**Variance** (S_h^2)	$\bar{\lambda}_1$	$\bar{\lambda}_2$
1	180	10	0.056	0.25	25	62	45.3	8154	125.789	35	49
2	180	10	0.056	0.25	51	112	86.8	15624	299.956		
3	180	10	0.056	0.25	67	153	108	19440	899.111	$\bar{\lambda}_1$ range	$\bar{\lambda}_2$ range
4	180	10	0.056	0.25	31	99	60.6	10908	530.044		
Total	720	40	——	1.00	——	——	——	54126	——	32~38	43~54

$\bar{\lambda}_1$ is the total number of people who arrive at the closed printing system every hour, $\bar{\lambda}_2$ is the total number of people per hour during peak hours (12:30-14:30), and the range of $\bar{\lambda}_1$ and $\bar{\lambda}_2$ is 95% confidence interval.

B. *μ estimation*

In the same way, according to different types of printing services, the data of 15 days were randomly sampled from the total sample (180 days) service time, as shown in Table 3.

Table 3. Printer single use time sampling

Layer (h)	**Randomly selected for 15 days (seconds)**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Print	44	55	38	47	67	72	67	69	88	74	44	65	59	61	52
Copy	26	36	46	27	35	26	45	67	35	29	34	33	34	46	39

Tab.4 Printer single use time statistic

h	**N*h***	**n*h***	***fh***	***wh***	**Min**	**Max**	**Mean** ($\bar{y}_h$)	**N*h*$\bar{y}_h$**	**Variance** (S_h^2)	**μ**
h1	180	15	0.167	0.50	38	88	60.12	10822	184.552	73
h1	180	15	0.167	0.50	26	67	37.2	6696	112.743	μ range
Total	360	30	——	1	——	——	——	17518	——	68~81

μ is the average number of printers per hour, and the range of μ takes a 95% confidence interval.

C. *Operation result analysis*

From the analysis of the results in the previous section, we can see that the service time is relatively balanced. Therefore, μ takes an intermediate amount of 74, and λ_T takes 50. As the number of input terminals configured is different, the value of the print request λ_m for each input is different, as shown in Table 5 below.

Tab.5 System operation index parameter table when μ=74

Parameters / **Number**	**n₂=2**	**n₃=3**	**n₄=4**	**n₅=5**	**n₆=6**
	λ₂=25	**λ₃=17**	**λ₄=13**	**λ₅=10**	**λ₆=8**
2	P_0=55.9% w_q=0 w_s=48.7s P_e＝25.3%	P_0=53.6% w_q=0.9s w_s=49.6s P_e＝27.9%	P_0=51.9% w_q=1.6s w_s=50.5s P_e＝29.9%	P_0=52.6% w_q=2.1s w_s=50.7s P_e＝29.6%	P_0=53.5% w_q=2.4s w_s=51.1s P_e＝29.1%

In particular, it is pointed out that the calculation of some basic parameters in the running indicator parameters in table 5 can be completed according to the LINGO function related to the closed form queuing theory. When λ=25, μ=74, $\rho_1 = \frac{\lambda}{\mu}$=0. 34,, c=2, n=2, there are:

```
lamda=25;mu=74; rho=lamda/mu; c=2;n=2;
load=n*rho;
Ls=@pfs(load,c,n);
lamdae=lamda*(n-Ls);
Lq = Ls- lamdae/ mu;
ws=Ls/lamdae;wq=Lq/lamdae;

P 效=( Ls- Lq) /c
end
```

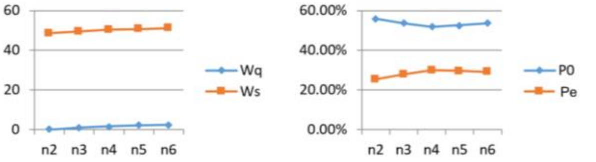

Fig. 3. Line diagram of operation index

It can be seen from Fig.3 that w_q and w_s increase with the increase of the input device, but the change is gentle, and the waiting time difference is within 1 second. It shows that for each input device, the number of print requests will increase correspondingly during the unit time period. At the same time, the system queue and stay time will increase, but the increase will gradually slow down. It can be seen that the less n value (within a reasonable range) the Shared printing system within a certain period of time, the greater the probability that the later users will actually wait longer. The overall printing efficiency and progress of the shared printer are affected, and the characteristics of fair and intelligent sharing printers cannot be fully reflected. The P_0 and P_e change nonlinearly with the increase of the input device, and the inflection point occurs when the input device is m=4, P_0 is the lowest and P_e is the highest. This indicates that the increase in input devices has an optimal solution for the efficiency of shared printers (here m=4).

IV. CONCLUSION

According to the existing configuration, this paper extracts library data in Shanghai University of Medicine & Health Sciences and calculates scientific and reasonable parameter values according to relevant principles such as data mining and sampling statistics.Operations are performed by using related software and function programs such as SPSS Modeler and LINGO, and the operation results are obtained, and a more appropriate service model scheme is obtained through analysis. The theoretical basis is sufficient, the calculation is scientific and reasonable, the operation steps are simple, and the results meet the expected expectations.

The difficulty of this study is that after determining the closed and finite source characteristics of the system, it is necessary to fully investigate the practical significance of each parameter in the queuing service model, which part of the initial access control data may come from, and the selection of operational indicators with guiding significance. The research results can provide a theoretical basis for library management and decision-making, and also provide a strong guarantee for improving library service quality and satisfaction.

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