Design of reservation model of teaching equipment in NC laboratory based on BS mode

Haibo Liu and Xinbo Zhang*

Mechanical and Automotive Engineering School,
Xiamen University of Technology,
Xiamen 361024, China
Email: yuezh@mls.sinanet.com
Email: xinboz@mls.sinanet.com
*Corresponding author

Qingzhong Gong

Department of Mechanical and Electrical Engineering,
Jimei University,
Xia'men 361024, China
Email: 3060958348@qq.com

Abstract: In order to solve the jobscheduling problem of CNC laboratory equipment concurrent reservation, the design method of CNC laboratory teaching equipment reservation model based on BS mode is proposed. By using BS mode, the equipment management structure of numerical control laboratory is designed hierarchically. The reservation time series model to realise the load transmission and information estimation in the process of reservation is then built. According to the statistical results, the reservation fitness function, reservation scheduling and reservation algorithm are designed. Based on this, the database security storage function and SMS processing function of the model are designed to realise the construction of teaching equipment reservation model in CNC laboratory. Experimental results show that compared with the traditional equipment design model, the model designed in this paper has higher reservation success rate and better application performance.

Keywords: BS mode; numerical control laboratory; teaching equipment reservation; statistical characteristic quantity; fitness function.

Reference to this paper should be made as follows: Liu, H., Zhang, X. and Gong, Q. (2023) 'Design of reservation model of teaching equipment in NC laboratory based on BS mode', *Int. J. Continuing Engineering Education and Life-Long Learning*, Vol. 33, No. 1, pp.54–68.

Biographical notes: Haibo Liu holds a Master degree from Xiamen University of Technology, with research direction towards numerical control technology, mechatronics technology, and intelligent manufacturing.

Xinbo Zhang is a Senior Engineer, and Master Tutor. He is the Director of Mechanical and Electrical Engineering Experimental Centre, Xiamen University of Technology. His research direction lies in CNC control technology, mechatronics technology, and intelligent manufacturing.

Copyright © 2023 Inderscience Enterprises Ltd.

Qingzhong Gong is an Associate Professor/Senior Engineer and Master Tutor. He is the Associate Head of the Department of Electromechanical Engineering, School of Mechanical and Energy Engineering, Jimei University. His research interests are in numerical control technology and intelligent equipment, electromechanical integration technology and intelligence, advanced materials and preparation.

1 Introduction

With the rapid development of higher education informatisation, experimental teaching is closely combined with digital information platform. The digital information platform can realise the sharing of experimental resources and online reservation, and increase the use range of all instruments and equipment. If the digital platform can be applied in the campus network (Fu et al., 2016), then all teachers and students can make an appointment to use the experimental equipment online; if the digital platform is applied on the national Internet, all companies and individuals can use these devices. If the platform runs on the Internet, the equipment can be used by all units and individuals outside the school, serving the local economy. On the basis of the current online sharing of university equipment, research on the reservation model of laboratory teaching equipment can effectively improve the utilisation rate of instruments and equipment, and has obvious social benefits.

Famularo et al. (2016) designed a multi-mode automatic reservation model of laboratory based on UML. Design the mobile client to ensure that the client can make an offline appointment. According to the business process, through the automatic reservation control circuit, to achieve the purpose of different personnel reservation. The Ethernet communication server is designed to provide more storage space for the data layer. Burke et al. (2017) gives a quantitative mathematical model based on the analysis of reservation process and sharing mode. According to the uncertainty of the problem and the actual situation of a large number of concurrent users, a heuristic algorithm based on problem decomposition is proposed. According to the SF strategy, the order of interval solution is determined, and the improved Dantzig algorithm is used to solve the single interval problem. In the process of solving, local backtracking adjustment is carried out, and finally neighbourhood search is carried out. In the practical application of the above traditional methods, the success rate of reservation still cannot meet the needs of students, and the efficiency improvement of model application is not obvious.

Therefore, this paper designs a reservation model of teaching equipment in CNC laboratory based on BS mode. The overall design scheme of the model is as follows:

1. In BS mode, the management structure of NC laboratory equipment is designed in layers, which are presentation layer, application layer and data layer. The reservation time series model is constructed to realise the load transmission and information estimation in the reservation process of CNC laboratory instruments.
2. According to the above load transmission and information estimation results, the statistical characteristics of equipment reservation are extracted. According to the statistical results, the reservation fitness function is designed, and the reservation scheduling and reservation algorithm are designed. Based on this, the database

security storage function and short message processing function of the model are designed to realise the construction of teaching equipment reservation model in NC laboratory.

3 Experimental verification, in the actual environment and the ideal environment, taking the appointment efficiency as the experimental comparison index, the designed model is compared with the traditional model.

2 Teaching equipment reservation model of NC laboratory based on BS mode

2.1 Structure design of reservation model in BS mode

The network operation mode of the numerical control laboratory model adopts BS structure, namely browser and server structure. The advantage of BS structure is to realise the terminal of b/s system for users to use browser in any system (Judge, 2018). The main thing logic is completed on the server side, only a small part of the transaction logic is completed on the client side. The model is easy to extend the function, simplify the load of client computer, reduce the maintenance cost and upgrade workload of the model.

2.1.1 Layer display

The display layer is the browser of the user's global wide area network, and is the communication contact between the data experimental model and the user. Users can call the software according to the model installed in the display layer to understand the detailed data of the model. The display layer mainly makes service request to the network experimental model program through the program browser. After the user authentication by the global wide area network, the web page required by the user is transmitted to the client through the transmission control protocol / Internet protocol. After the user accepts the file, it is displayed on the global wide area network browser (Vale, 2016).

2.1.2 Logic layer

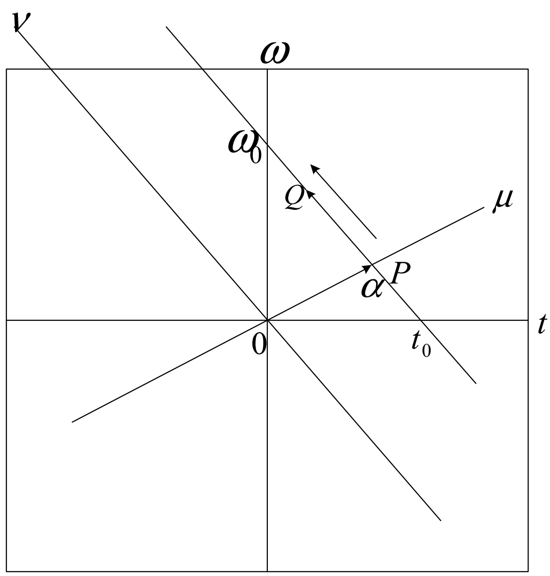
The logic layer is the main part of the whole model construction. According to the requirements of the clients, the corresponding program is extended according to the requirements of the global wide area network server. The data is applied and processed by combining the method of structured query language and database connection. The processed results are transmitted to the server of the global wide area network, and then the data is transmitted to the client (Sturtevant et al., 2016). The logic layer of the whole model is divided into: teaching management of teachers, experimental operation of students, monitoring and management of the model. Each logical application has its own transaction, and has a unified interface of display layer and data layer. Therefore, the logical layer is a collection of transactional applications with canonical connectors.

2.1.3 Persistent layer

The persistence layer is located in the database server. It mainly accepts the requirements of the WAN server for data operation, facilitates the data modification, search and update, and transfers the operation structure to the application server. Persistence layer is the core of the whole model, which needs to have the management, service and storage functions of massive data.

The model is a collection of applications running in the network environment, developed with. Net framework technology (Khan et al., 2016). This technology is adopted because it has a managed execution environment and integrates various programming languages. It can make all kinds of applications in the model communicate and share data through Internet, which is not controlled by operation mode, network connected equipment or computer language, and conforms to the characteristics of BS mode.

Figure 1 Block diagram of instrument reservation area in NC laboratory



2.2 Reservation algorithm of teaching equipment in numerical control laboratory

2.2.1 Laboratory instrument control model

In order to realise intelligent reservation control of numerical control experimental instruments, it is necessary to establish a load balance control model of experimental instruments management including cross regional equipment reservation information transmission control based on the structure of reservation model, and support vector machine model is used for the classification and balance control of CNC experimental instruments adjustment (Victoriano et al., 2016). In this paper, support vector machine model and principal component method are combined to complete the information value and quantity estimation and load transfer in the process of experimental instrument reservation. The reserved laboratory instrument area is shown in Figure 1.

The distribution calculation model of the time series of CNC laboratory instrument reserve is established. The statistical analysis method and regional statistical analysis method are used to make the distribution of numerical control laboratory instrument and equipment reserve uniform (Ma et al., 2017). The mathematical expression of the sample sequence is as follows:

$$Q = \{Q_1, Q_2, ..., Q_i\} \tag{1}$$

Among them, Q_i is the random distribution of d-dimensional numerical control experiment reservation time series, and the random variables of numerical control experimental instrument reservation are independent. Fuzzy association rules mining method is used to realise adaptive feature detection of CNC experimental instrument reservation (Limpanuparb et al., 2019), and automatic correlation matching filter detection technology is used to reconstruct the reservation information model of numerical control experimental instrument. Combined with intelligent management, the probability density calculation function of instrument reservation is as follows:

$$f(U) = \frac{1}{b-a} I[a, b) \tag{2}$$

$$I = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\mu^2}{2\sigma^2}} \tag{3}$$

Among them, [*a, b*] is the reservation allocation interval, *I* is the rectangular distribution function of numerical control laboratory instrument reservation calculation, σ and μ are the probability law parameters of random variable value. The discrete sampling method is used to design the information sensing model in the instrument reservation of numerical control laboratory. If the *h* of each node reserved by the instrument is adjusted, the likelihood formula is as follows:

$$D(s) = \int_{U=1} f(U) \tag{4}$$

Considering the influence of the reservation time, the formula of the distribution of laboratory instrument reservation is obtained as follows:

$$c = \frac{1}{|L| \cdot N_t} \left\{ \sum \log_2 [1 + SINR_i] \right\} \tag{5}$$

Among them, $|L|$ is the reservation parameter in different allocation intervals, N_t is the average reservation times in a time interval, and $SINR_i$ is the signal-to-noise ratio uniformity parameter. By constructing the integral cross term of balanced configuration, the output of the reserved time series of numerical control experimental instruments is obtained as follows:

$$D = \frac{1}{b-a} \times c + f(U) \tag{6}$$

Combined with the above formula, the reservation time series model is designed according to the cross joint probability density estimation method. Therefore, the fuzzy adjustment and feature extraction of experimental instrument reservation are implemented. The reservation sequence model is as follows

$$T = \frac{g[a,b]\,p[a,b]}{N_t + D} \tag{7}$$

Among them, *g* [*a, b*] is the instantaneous reservation increment value of [*a, b*] interval, and *p* [*a, b*] is the success rate value of [*a, b*] interval.

2.2.2 Statistical characteristic quantity of laboratory instrument reservation

The statistical characteristic quantity of instrument reservation is extracted, and the feature vector set of each data element is constructed. Taking local function and all function as planning function (Zeiner et al., 2019), the mixed function of numerical control experimental instrument reservation is obtained as follows:

$$K = \beta K_{poly} + (1-\beta)K_{rbf} \tag{8}$$

Among them, K_{poly} is the fuzzy kernel function of NC instrument reservation, K_{rbf} is the local function of NC laboratory instrument reservation stability, and β is the kernel function width value.

Combined with the hybrid kernel function and the global kernel function, the statistical characteristics of the reservation information of CNC laboratory instruments are extracted (Flaherty et al., 2017). The fuzzy function of reservation information of numerical control experimental instrument is obtained by finite sample training, and the nonlinear operator is constructed to represent the information transmission environment of instrument reservation:

$$\alpha = \Phi \times \left(\frac{Density_i}{\sum_i Density_i} + \frac{AP_i}{AP_{init}} \right) \tag{9}$$

$Density_i$ is the dense relationship between the reservation node *h* and the control node.

Under the control relationship, the hidden characteristic parameters are obtained as follows:

$$\varepsilon = \frac{\sum_{i=1}^{n} \mathrm{Re}(U) \times \alpha}{a_h + b_h} \tag{10}$$

Among them, Re (*U*) is the number of user nodes in the laboratory, a_h is the customer information level parameter, and b_h is the relationship parameter between regions. According to the information sensing model designed in the process of instrument reservation in NC laboratory, the statistical characteristics of instrument reservation in NC laboratory are extracted.

2.2.3 Reservation performance improvement

Based on the above-mentioned time series model of CNC laboratory instrument scheduling and the design of information sensing model of discrete sampling method in the process of CNC laboratory instrument reservation, the algorithm of CNC laboratory instrument reservation is optimised. A greedy algorithm for control reservation is proposed. According to the application status of the instrument, the use degree of the instrument is determined, and the convergence control coefficient is obtained as follows:

$$f^n = \frac{F_i - F_{avg}}{F} + m \tag{11}$$

Among them, m is the parameter of recommended reservation times for laboratory instruments, F_i is the characteristic parameter of greedy algorithm in NC experimental instrument reservation, F_{avg} is the function of average fitness reservation algorithm, and is the user control parameter of instrument reservation, which is used to control the size of f^n. If $f^n \geq H$, the results show that the convergence of CNC laboratory instrument reservation is poor, so the convergence should be controlled by adjusting the instrument reservation control objective function; when $f^n < H$, the laboratory instrument reservation is controlled by user feature discovery and convergence. If the user data of the instrument reservation is not comprehensive (Pinger et al., 2018), the gradient reduction method can be used to optimise the processing, so as to realise the reservation of laboratory instruments as follows:

$$\eta = \frac{V_{\max} - V_{\min}}{\delta^2} \tag{12}$$

Among them, $V_{\min}$, V_{m} is the characteristic value recommended by laboratory instrument reservation. According to the specification mining and some optimisation control methods, the recommended update function is as follows:

$$V = \frac{\eta}{q}\left\{\left[(1-\alpha)\eta + 1\right](K-1)\delta^2\right\} \tag{13}$$

Among them, q is the maximum cycle parameter adjusted by the instrument. According to the chaos mapping method, the management and control of experimental instrument reservation process is completed (Jankowski and Wozniak, 2016). The ergodicity and universality of the reservation of experimental instruments are analysed through the balance control management mode:

$$F' = \frac{1}{\chi}\sum_{i=1}^{\chi}(f_i - y_i)^2 \tag{14}$$

Among them, f_i is the best predicted reference value in the reservation algorithm, y_i is the actual parameter of the current instrument status, and χ is the sample parameter collected by the customer of the instrument reservation. According to greedy algorithm, intelligent optimisation and sorting of instrument reservation are carried out to improve the rapid reservation of instruments.

2.2.4 Realise intelligent priority of reservation

The greedy algorithm and regional environment are combined to realise the regional information processing of laboratory instrument reservation, and the input sample data set $W = \{w_1, w_2, \ldots, w_N)$ is obtained, in which N is the number of samples of laboratory instruments, and the historical distribution is $\{x_i\}_{i=1}^{N}$. The greedy optimisation expression of numerical control laboratory instrument reservation is as follows:

$$P = \frac{N_m(t+a)+V_i^d(t)}{B_m(t+a)\times P_i^d(t)} + F' \tag{15}$$

Among them, $V_i^d(t)$, $N_m(t+a)$, $P_i^d(t)$ and $B_m(t+a)$ are the conduction coefficients and related characteristics of the greedy algorithm at the current time and the next moment. In $[V_{\min}, V_{\max}]$ the scheduling of intelligent instruments in NC laboratory is obtained as follows:

$$\phi = \varpi\left(R_1 \times C_1 + R_2 \times C_2\right) \tag{16}$$

Among them, C_1 and C_2 are the scheduling technical parameters, R_1 is the gradient search radius stored by the instrument, R_2 is the total search threshold of the instrument storage, and ϖ is the value of inertia weight stored by the instrument. The formula for calculating the influence of instrument reservation time series is as follows:

$$E(X) = \sum_{i=1}^{\infty} \phi \times P \tag{17}$$

According to the above analysis, the state space equation of laboratory instrument reservation is linearised to realise the automatic scheduling and sequencing of numerical control experimental instrument reservation, and improve the automatic reservation ability of numerical control experimental instrument

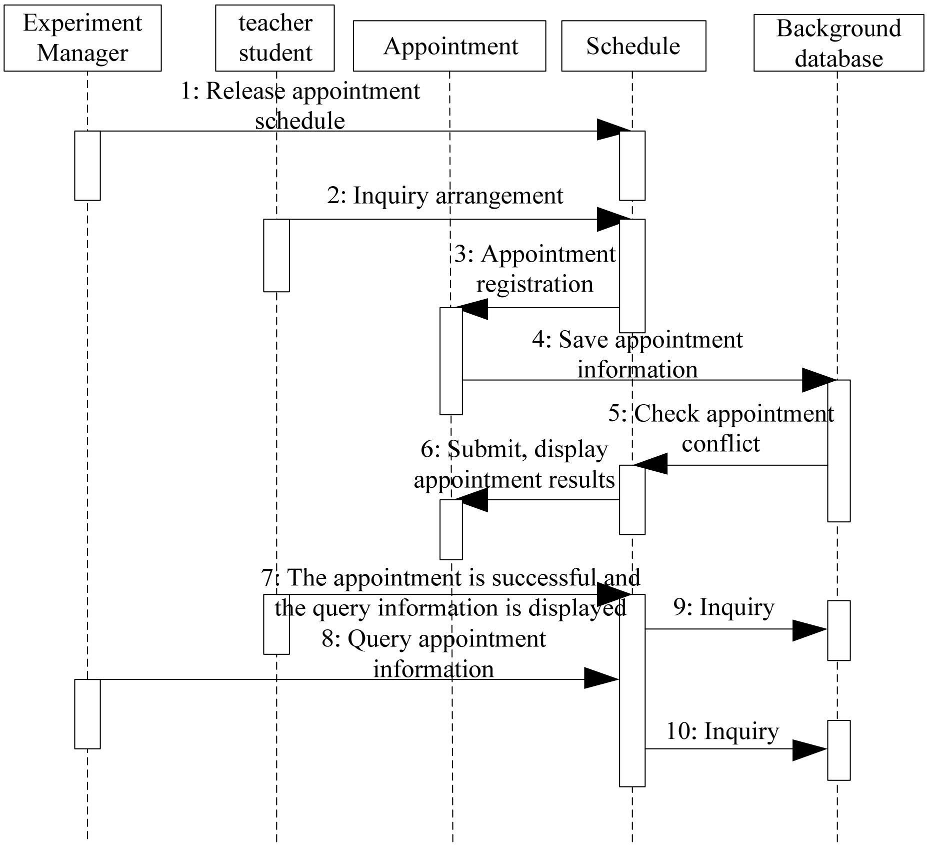
$$C = \sum_{i=1}^{n} E(X) + \phi P \tag{18}$$

2.3 Model function design

Rational Rose 2003 Gonalves et al. (2020) is used to establish the reservation model of CNC laboratory equipment. In the process of object-oriented modelling, the dynamic behaviour of the model is mainly represented by sequence diagram. The horizontal axis represents different objects, and the vertical axis represents time. The reservation sequence of experimental equipment established by UML Yu and Yeh (2020) is shown in Figure 2.

According to the analysis in Figure 2, the manager of the experimental instrument should verify the appointment information of teachers and students in real time, and give the results. In the database security storage function, the mobile terminal information processing function is designed (Hongzhou and Lixia, 2018). Finally, the software function is designed according to the reservation process.

Figure 2 Composition of teaching equipment reservation sequence in NC laboratory



2.3.1 Security management of instrument reservation data

The design of multi-mode automatic reservation model should establish a unified database, which is an important part of the reservation model design. The data processing of instrument reservation is:

$$d(v) = z + (i + j) + (\alpha + \beta) \tag{19}$$

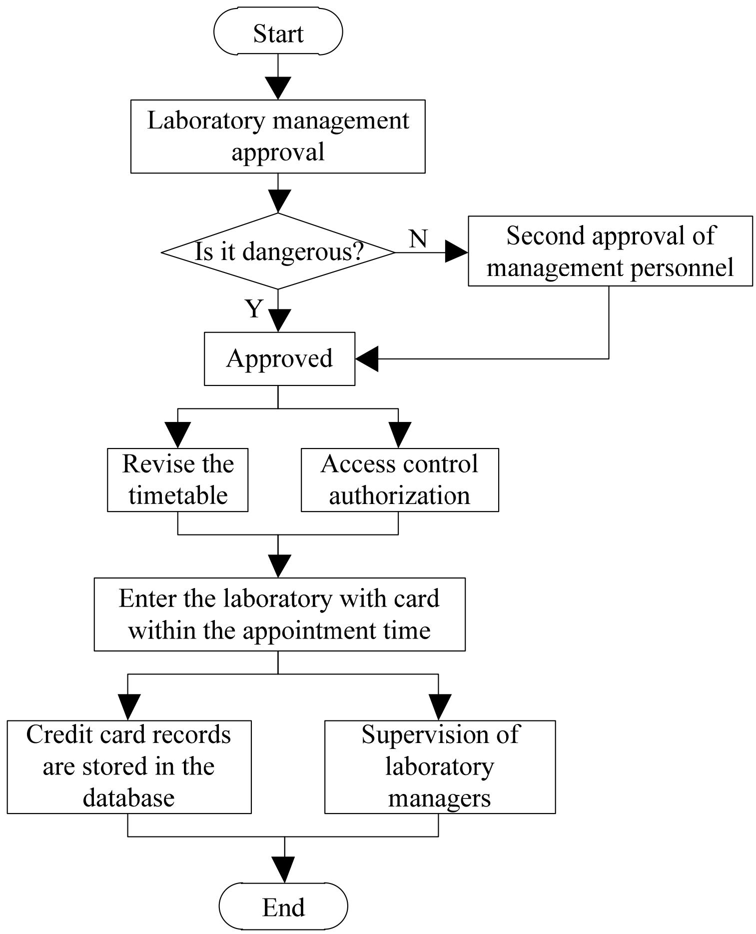
Among them, $d(v)$ is the minimum value of the result of processing information reserved by the application; i is the variable of the user's first reservation demand data; j is the function of missing data in the reservation data management; z is the function with the least risk in the processing structure; α and β are the variables and conjugate coefficients in the same information processing respectively.

The reservation information formula of safety reserve is as follows:

$$W(g)_{\min} = \sum_{i=1}^{n} \alpha_i(-g_i) - \beta z\left(\frac{1}{\beta}\sum_{i=1}^{n} y_i g_i\right) \tag{20}$$

Among them, $W(g)$ is the minimum parameter of storage information security (Wang, 2020); g is the hierarchical function of data security storage. All security data are stored in the database, and SMS processing function is designed.

Figure 3 Experimental teaching reservation structure



2.3.2 Management of SMS reception

The dte-dce standard interface is developed according to the GSM global mobile communication model jointly developed by different manufacturers (Zhang et al., 2018). The single-chip microcomputer in the service layer can send at instructions to the GSM through the serial port to realise the control of sending and receiving short messages in the global mobile communication mode (Chen et al., 2018).

Numerical control experimental teaching equipment booking steps are shown in Figure 3.

In the experimental teaching appointment step, we can see that the model determines whether the user logs in or not through dialogue. If there is no login, the user needs to select all parameters of this class and jump to the login page to fill in the page. After users fill in all the information, the model first queries whether the reservation information exists in the reservation data, so as to prevent multiple users from making an appointment at the same time. After confirming that no one has made an appointment, the reservation information is sent to the user successfully.

3 Experimental results

In the network server construction environment, the relevant data information provided by the laboratory central database is used as the simulation experiment data set of traditional model and design model.

3.1 Laboratory data extraction

The information of relevant members is extracted from the database of public numerical control laboratory, and the data is trained and processed by bilateral filtering method. The member information is shown in Table 1.

Table 1 Member information analysis

Login personnel	*User name*	*Data type*
Teacher information	Tea_id	Interior
Login information of NC teachers	Tloginame	Varchar
CNC professional teacher login password	TUser_password	varchar
Numerical control student number	Stu_id	Int
Student login name of numerical control major	Stu_loginame	Varchar
CNC students' login password	Stu_ password	varchar
NC laboratory manager number	Adm_id	Int
Login name of NC Laboratory Manager	Aloginame	Varchar
CNC laboratory administrator login password	AUser_password	varchar

According to the member information in Table 1, check the corresponding appointment experiment content, as shown in Table 2.

Table 2 Appointment experiment content

Serial number	*Number of people*	*Appointment of experiment content*
1	10	PCB high speed design course
2	20	MATLAB training and Simulink course
3	45	LabVIEW course
4	50	Motor technology course
5	40	STM32 MCU course

In the above experimental data and experimental environment, the overall experimental scheme is set as follows: in the ideal environment and the actual environment, the reservation effect is taken as the experimental comparison index, and in general conditions, the reservation efficiency is taken as the experimental comparison index, and the designed model is compared with the traditional model.

3.2 Comparison of appointment effect

The experiment contents 1, 2 and 4 are selected from the successful appointment experiment. The effect of traditional reservation mode and the reservation mode designed in this paper is compared and analysed.

3.2.1 In an ideal environment

In the ideal environment, there is no other interference. The two reservation models are shown in Table 3.

Table 3 Reservation effect of two models in ideal state

Number of experiments/times	*5*	*10*	*30*	*50*
Famularo et al. (2016)	88%	85%	79%	75%
Burke et al. (2017)	87%	83%	76%	72%
The model of this paper	98%	98%	97%	92%

In the traditional model, when the number of experiments is 5, the reservation effect of Famularo et al. (2016) model is the best; when the number of experiments reaches 50, the experimental reservation effect of Burke et al. (2017) model is the worst, but it also keeps above 70%.

When the number of experiments is 5 and 10, the reservation effect is better, reaching 98%. When the number of experiments is 50, the reservation effect of the designed model is poor, but it also reaches 92%.

Compared with the two models, we can see the effect of reservation. In the ideal environment, the two models have better reservation effect, but the reservation model designed in this paper has better effect than the traditional reservation model.

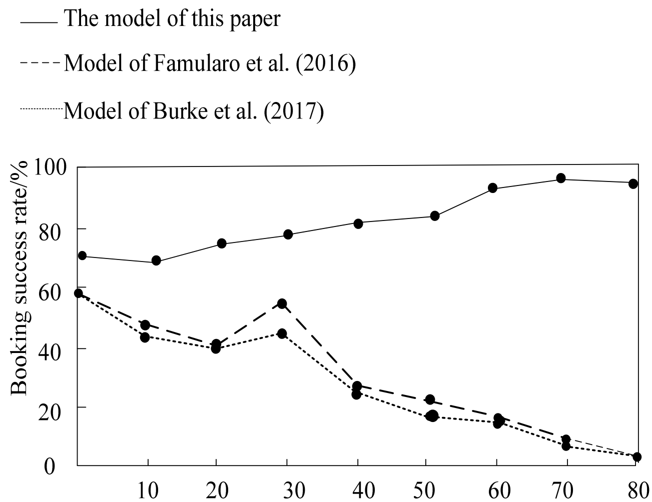
3.2.2 Under the actual environment

In the implementation, the two environments will be affected by network, time, distance and other factors, resulting in ideal booking effect. Compared with the traditional reservation model, the proposed mobile client model has better performance. In order to verify the results, experimental comparison is carried out, as shown in Figure 4.

As can be seen from Figure 4, the maximum reservation effect of the two traditional reservation models is less than 70%, and the minimum reservation effect is 3%. Therefore, the actual situation has a great impact on the traditional reservation mode. The minimum reservation rate is more than 70% and the highest reservation rate is 97%. The results show that the design of mobile client improves the efficiency of reservation.

By comparing the two models, we can see that the reservation model designed in this paper has better reservation effect than the traditional one.

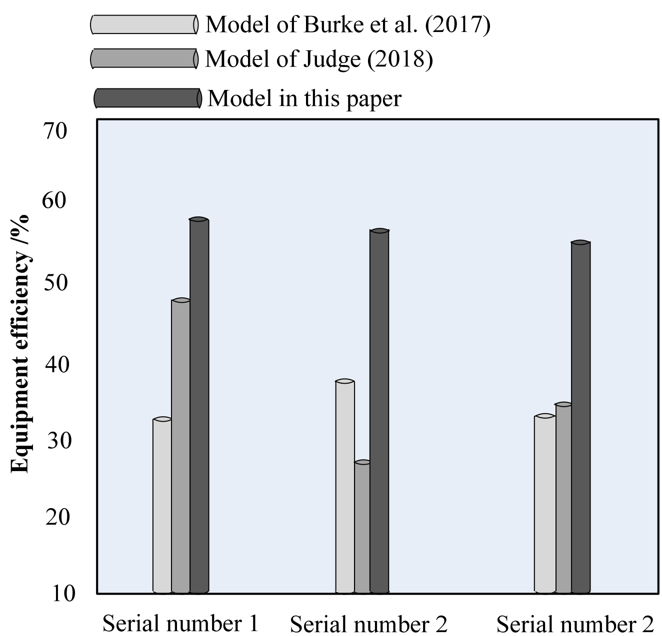
Figure 4 Comparison of two reservation models in actual environment



3.3 Comparison of appointment efficiency

In order to more accurately verify the method proposed in Burke et al. (2017), the instrument efficiency of this method is compared with that of the traditional method, and the comparison results are shown in Figure 5.

Figure 5 Efficiency test results of different NC equipment reservation models (see online version for colours)



It can be seen from Figure 5 that the use efficiency of the instrument is significantly higher than that of the traditional method after using this method to reserve CNC laboratory instruments. The experimental results show that this method can effectively improve the reservation and efficiency of experimental instruments.

4 Conclusions

At present, the parallel reservation problem often occurs in the reservation process of CNC laboratory equipment, and the equipment cannot be effectively scheduled, which reduces the use efficiency of the equipment. Therefore, the design method of teaching equipment reservation model based on BS mode is proposed. In order to enhance the management of NC laboratory equipment, the management structure of NC laboratory equipment is designed based on BS mode. On this basis, the algorithm of teaching equipment reservation is designed. And the model can realise the function of database security storage and SMS processing. Experimental results verify the effectiveness of the proposed model. However, due to the lack of practical application environment and conditions, my model only stays in the stage of theoretical analysis. Therefore, in the future research, the real application effect of the proposed model will be obtained in practical application, which will provide reference for further research in this field.

Acknowledgements

The authors gratefully acknowledge support from the Xiamen University of Technology (XMUT). This work is supported by the 2018 Xiamen science and technology plan external cooperation project, (Grant No. 3502Z20183052), and 2019 Quanzhou science and technology project, (Grant No. 2019C103).

References

Burke, R., De Jonge, N., Avola, C. and Forte, B. (2017) 'A virtual engine laboratory for teaching powertrain engineering', *Computer Applications in Engineering Education*, Vol. 25, No. 6, pp.18–25.

Chen, T., Wang, Y.C. and Lin, Z. (2018) 'Predictive distant operation and virtual control of computer numerical control machines', *Journal of Intelligent Manufacturing*, Vol. 28, No. 5, pp.1061–1077.

Famularo, N., Kholod, Y. and Kosenkov, D. (2016) 'Integrating chemistry laboratory instrumentation into the industrial internet: building, programming, and experimenting with an automatic titrator', *Journal of Chemical Education*, Vol. 93, No. 1, pp.175–181.

Flaherty, A., O'Dwyer, A., Mannix-Mcnamara, P. and Leahy, J.J. (2017) 'Evaluating the impact of the 'teaching as a chemistry laboratory graduate teaching assistant" program on cognitive and psychomotor verbal interactions in the laboratory', *Journal of Chemical Education*, Vol. 11, No. 9, pp.1831–1843.

Fu Z.Y., Wu, F.C., Mo, C.L., Deng, Q.J., Meng, W. and Giesyde, J.P. (2016) 'Comparison of arsenic and antimony biogeochemical behavior in water, soil and tailings from Xikuangshan, China', *Science of The Total Environment*, Vol. 539, No. 1, pp.97–104.

Gonalves, M.A.F., Lorini, F.J., Benetti, C., Eckhardt, M. and Scheuer, C.J. (2020) 'Universal parameter language for the programming of numerical controlled machines', *International Journal of Advanced Manufacturing Technology*, Vol. 11, No. 9, pp.1–13.

Hongzhou, L. and Lixia, S. (2018) 'Design of testing period for reliability assessment of numerical control machine tools considering working conditions', *Mathematical Problems in Engineering*, Vol. 21, No. 8, pp.1–8.

Jankowski, M. and Wozniak, A. (2016) 'Mechanical model of errors of probes for numerical controlled machine tools', *Measurement*, Vol. 77, No. 4, pp.317–326.

Judge, M. (2018) 'Large-scale laboratory teaching for first-year EEE undergraduates (Vol. 54, p.164, 2017)', *International Journal of Electrical Engineering Education*, Vol. 55, No. 1, pp.88–88.

Khan, U., Ahmed, N., Bin-Mohsen, B., Mohyud-Din, S.T. (2016) 'Nonlinear radiation effects on flow of nanofluid over a porous wedge in the presence of magnetic field', *International Journal of Numerical Methods for Heat and Fluid Flow*, Vol. 27, No. 1, pp.48–63.

Limpanuparb, T., Kanithasevi, S., Lojanarungsiri, M. et al. (2019) 'Teaching boyle's law and charles' law through experiments that use novel, inexpensive equipment yielding accurate results', *Journal of Chemical Education*, Vol. 96, No. 1, pp.169–174.

Ma, X.Y., Zhao, Y.L., Jia, F.X., Song, Y.K. and Xie, Y.C. (2017) 'Utilization of Caenorhabditis elegans in laboratory teaching of genetics', *Hereditas(Bjing)*, Vol. 39, No. 8, pp.30–65.

Pinger, C.W., Andre, C., Savannah, S. and Spence, D.M. (2018) 'Plate reader compatible 3D-printed device for teaching equilibrium dialysis binding assays', *Journal of Chemical Education*, Vol. 95, No. 6, pp.1662–1667.

Sturtevant, B.T., Pantea, C. and Sinha, D.N. (2016) 'High frequency signal acquisition using a smartphone in an undergraduate teaching laboratory: applications in ultrasonic resonance spectra', *Journal of the Acoustical Society of America*, Vol. 140, No. 4, pp.2810–2816.

Vale, M.R. (2016) 'Surveillance cameras and their use as a dissecting microscope in the teaching of biological sciences', *AJP Advances in Physiology Education*, Vol. 40, No. 1, pp.116–118.

Vitoriano, F.A., Teles, V.L.G., Rizzatti, I.M. and Pesssoa de Lima, R.C. (2016) 'Promoting inclusive chemistry teaching by developing an accessible thermometer for students with visual disabilities', *Journal of Chemical Education*, Vol. 93, No. 12, pp.2046–2051.

Wang, X. (2020) 'Research on human-machine interface optimization design of numerical control machine tools in ocean engineering based on visual communication perception field', *Journal of Coastal Research*, Vol. 115, No. 1, pp.322–356.

Yu, T.H. and Yeh, S.S. (2020) 'Using multiple performance index for best-fitted design of computer numerical control turning process', *Journal of the Chinese Institute of Engineers*, Vol. 43, No. 2, pp.1–10.

Zeiner, M., Viehauser, P. and Steiner-Friedmann C. (2019) 'Teaching laboratories at a slower pace: introduction of photocomics as easy-to-use laboratory instructions', *Journal of Chemical Education*, Vol. 96, No. 11, pp.2518–2523.

Zhang, C., Zhao, H., Zhu, X., Zhao, S. and Jiang, C. (2018) 'Design of an ultraprecision computerized numerical control chemical mechanical polishing machine and its implementation', *Optical Engineering*, Vol. 57, No. 1, pp.140–145.