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A Comparative Analysis of Biometric and Manual Attendance Measures using Queueing Theory

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Abstract: *We can see that in many companies manual methods are commonly used for taking attendance. However, this may lead to the possibility of staff giving dummy attendance for absent colleagues. This study aims to compare the efficiency of a biometric-based attendance system with that of manual attendance. To evaluate the service efficiency of the two attendance methods, the study uses a single and single server queueing model. The variables measured include the arrival rate* (λ) *and service rate* (μ)*, which were analyzed simultaneously Primary data were obtained through the observation of both biometric and manual attendance systems. The results indicate that the biometric attendance system was more efficient than the manual attendance system, based on the performance measures of the queueing system. Therefore, the findings suggest that implementing a biometric-based attendance system can help improve attendance tracking and reduce the possibility of fraudulent attendance practices.*

Keywords: Queueing analysis, service time, biometric attendance, arrival time

I. INTRODUCTION

The biometric attendance machine is a tool that can optimize the tracking of employee time records, productivity, and attendance, while reducing issues such as absenteeism, lateness, and truancy (Tripathi Jain 2020). Historically, attendance monitoring and evaluation have been conducted using time clocks and timesheets (the manual approach to taking attendance). However, monitoring and evaluating attendance is critical to effective time management, which can boost employee attendance and motivation. It extends beyond simply tracking attendance(Debrah JO 2020).It is widely believed that utilizing biometric attendance systems is the most convenient way to monitor employee productivity and attendance in businesses, nonprofit organizations, and volunteer organizations. Biometric attendance systems are particularly helpful for workforce analysis, daily attendance monitoring, keeping statutory registers, maintaining leave records, calculating overtime, and sending data to the payroll system(Pooja Saini 2018).Most current manual employee attendance systems require that employees manually record their attendance when they enter and leave the office. However, as it is not an electronic system, it typically lacks automation and can result in several issues. For example, workers may need to spend time locating and signing their names on the attendance sheet, and there is a risk that the attendance sheet may be misplaced or kept away from employees due to suspected improper activities.Thanks to the invention and implementation of biometric attendance systems, organizations can now systematically manage the attendance of their personnel (Adewole K. S. 2014). Biometric attendance systems provide a more efficient and reliable method of tracking employee attendance, as they eliminate the need for manual record-keeping and prevent fraudulent practices.The employee clocking system includes a database containing employee information, and it can assist administrators in updating and manipulating this database (S. Wang 2016). In modern commercial transactions, customers are typically required to authenticate themselves using control mechanisms such as identity cards, ATM cards, driver's licenses, and health cards (Debrah Joshua Osei, 2020). However, carrying multiple cards and remembering various passwords for different services can be a challenging issue for both individuals and corporations (Tan TN 2019). Therefore, a safe and efficient identity and access control system is critical for the successful implementation of an employee clocking system.

A mobile application for student attendance and mark management system. Using this system,the subject handlers, staffs or the authorities can verify the number of students present or absent in the class meeting sessions. t gives a prior intimation to students as soon as their attendance goesbelow the specified percentage through an alert message (D. Asir Antony Gnana Singh 2017).The world is rapidly transitioning to the digital age, with the growth of smart systems and digitization. Biometric technologies utilize features such as fingerprints, faces, iris, retinal patterns, palm prints, voices, and handwritten signatures to confirm identity. Among these biometric features, the fingerprint is the most commonly used and widely accepted for automatic personal identification in biometric authentication (Pang S 2019, Harikrishnan D 2019).

II. LITERATURE REVIEW

Dibyahash Bordoloi (2021) utilized a Raspberry Pi, an embedded computer running Linux, with PostgreSQL for database management, a PHP web application, and a U.are.U 4500 fingerprint reader. They stored the fingerprint image binary in the database and used the flann index kdtreeopen CV method to compare the features of two fingerprint images (Debrah JO 2020). The purpose of their study was to propose using biometric employee clocking to reduce high truancy rates in organizations. The results showed that the system had a high degree of accuracy, with a TAR value of 99.7%, which is higher than previous research findings. (Janelle Mason 2020) investigates the biometric system and the authentication process using periocular biometrics specifically. We integrate this approach with the healthcare system to provide an advanced method to identify the patients securely. The prototype framework utilized multiclass CNNs, specifically, a modified version of AlexNet, to test the accuracy of identifying the patient for each periocular biometric image captured on a smartphone; the TPR achieved approximately 98%. (Santhi Priya 2016) The high accuracy rate suggests that employees may find it challenging to check in or out for absent coworkers. These findings have the potential to increase employee performance, improve attendance security, facilitate fast and easy data retrieval, enable simple staff supervision, and prevent impersonation in attendance records.

A study utilized a Raspberry Pi-based attendance system that utilizes facial detection and identification(R. M. Pawar 2018). The database stores each student's specific facial image, and the camera captures the entire class during the class, detecting and identifying each student's face image by comparing it to a saved image in the database (Anilkumar Patil 2017). Another proposed solution is an IoT-based attendance system based on Node MCU (ESP8266) and a fingerprint scanner (A. Das 2017). The solution includes a portable device that includes an R-305 fingerprint reader, an ESP8266 with Wi-Fi, an Arduino for attendance, and a MySQL database to store data. However, the system has a limitation that the teacher must restart the attendance-taking procedure if the internet connection is lost (Piyush Devikar 2020). The authors developed and installed a biometric attendance system using a fingerprint scanner and ESP8266 (S. S. Rupnar 2018)., which uploads the Roll no/ID of the recognized finger to a Google Spreadsheet using the Pushing Box API service (Mahesh Sutar 2016). The use of RFID technology was proposed in a smart attendance system (Rajan Patel 2012). An RFID-based student attendance system was proposed, which would be integrated with ubiquitous computing systems. The RFID (C. Li et. al. 2012)., readers would be placed close to classrooms, and the instructor would activate the reader with a single click during class, after which the antenna reader would scan each card connected to the student's identity card and transmit the collected data to the main server (Ching Hisang 2012). Another suggestion was to install an RFID-based Smart Classroom Roll Caller System (SCRCS) in each classroom, which would read the IDs at the beginning of each class and display the total number of actual attendances on the SCRCS LED display. The academic office would then collect all of the students' attendance records (Arun Kumar S 2019).

A safe and efficient identity system for attendance is crucial for maintaining security and accuracy in various environments, such as workplaces, educational institution, and events. This system ensure that only authorized individuals can gain access, preventing unauthorized entry and potential security breaches. By incorporative technologies like biometrics, RFID, it enables seamless integration with the attendance management system, streamlining attendance tracking and reducing administrative burdens. This system can achieve a robust attendance system that ensures safety and efficiency (Smith et. al., 2020).

A smart attendance system that utilizes a combination of Raspberry Pi and ultrasonic sensors was proposed and implemented. The system comprises four modules: a smart projector module, an ultrasonic sensor module connected to a Raspberry Pi for hand gesture control of presentations, a smart attendance module with a fingerprint sensor integrated inside the Raspberry Pi, and a module for faculty to access information. The fingerprint biometric capability is used to identify students and record their attendance in an Excel spreadsheet (Sifatnur Rahman 2018).

Biometric attendance has gained significant popularity due to their accuracy, reliability, and ease of use. These systems utilize the unique fingerprint patterns of individual for identification and verification purposes. By capturing and storing fingerprint data, organizations can create a secure and efficient method of recording attendance. The use of fingerprint as a biometric identifier offers a high level of accuracy and prevents fraudulent practices such as buddy punching. Moreover, finger print based attendance system are user friendly and require minimal training for individual to use. According to (Zang et. al. 2019) Fingerprint based attendance system showed a 98 % accuracy rate and improved overall attendance management. This underscores the effectiveness of fingerprint-based attendance system in enhancing attendance tracking and promoting accountability.

A fingerprint-based attendance system was developed by utilizing Minutia's fingerprint recognition feature. The authors created a user interface for the teacher to log in and take attendance. The system will then compare the captured fingerprint with the stored fingerprints in the database to recognize the student and record their attendance (Pradeep Kumar MS 2017). Similarly, another attendance system was implemented using a fingerprint scanner and a Raspberry Pi. The authors used an open cv programming tool with a python script to compare the database fingerprint with the captured fingerprint and log attendance in an excel file. This file is then uploaded to the cloud (Ezema LS 2015).

A fingerprint-based attendance system was established utilizing a micro-controller, a fingerprint reader, an LCD, a real-time clock, and serial connection. The software aspect, which accepts attendance records from the hardware side, was designed with Visual Basic. The attendance data was tracked and saved using Excel (Arunraja A 2019). Another attendance system was also implemented where each student was provided with an IP-specific smart card equipped with an ESP8266 module with Wi-Fi connectivity. The central server stored the name, roll number, and IP address (connected to the ESP8266). The Raspberry pi was used to relay the IP address of each ESP8266 connected to the current students to the main server for attendance tracking (Thein MM 2015).

A passive attendance system was developed, which utilizes both RFID and ZK fingerprint reader technology. The SQL database stores the registered fingerprints. To take attendance, the RFID and fingerprint scanners are used, and attendance is recorded only if both IDs match, thereby preventing students from using unauthorized RFID tags. The implemented GUI is efficient (Aniket Shete 2017). Another system developed is an IoT-based portable attendance gadget that uses an ATMega16 GPS module to make it portable and sends attendance to the server. The GUI was developed using software programs written in C++, and Rapid Application Development (RAD) techniques were used for GUI creation.

III. KENDALL'S NOTATION FOR REPRESENTING QUEUEING MODELING

The nomenclature used to describe a queue organization model includes six positions that specify its characteristics, such as limited or unlimited space, limited or unlimited population, etc. The structure of the nomenclature is (a/b/c)/(d/e/f), where:

- a- denotes the probability distribution of the inter-arrival times
- b- denotes the probability distribution of the service times
- c - represents the total count of servers in the system.
- d- denotes the capacity of the system (i.e., the maximum number of customers it can hold)
- e- denotes the population size (finite or infinite)
- f- denotes the service discipline (i.e., the rule for selecting the next customer to be served from the queue).

An M/M/1/∞/∞/FIFC model describes a queue organization model in which:

- The inter-arrival and service times are both exponentially distributed (M is obtained from the Markovian property of the exponential distribution).
- There are no limitations on the number of customers that can access the single server in the facility.
- Customers arrive from a population that is considered infinite in the sense that the arrival of an individual does not modify the probability of the next arrival.
- FIFC (First In, First Consider) is the most frequent way in which the next customer to be served is chosen from the queue. (Kendall DG 1953).

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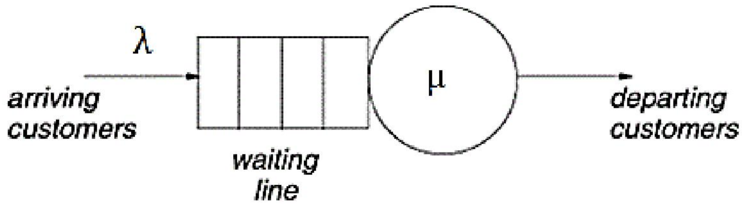
IV. STRUCTURE OF QUEUEING PACKAGE

The queueing package introduced by Pedro Cañadilla Jiménez (2017)utilized the S3 special class of functions in R to create queueing models. This type of function enables the users to construct several queueing models in the same standardized and straightforward manner. This model was generated through the implementation of these steps: The New-Input function was used to create the model inputs.

1. The inputs were optionally verified with the Check-Input function.
2. The Queueing Model was created by calling the function.
3. A summary of the model was printed using the print function or a specific performance measure such as W.

While step 2 is not required since it is executed when the Queueing Model function is called, it is recommended to verify the inputs to better understand the data and to correctly build the model. The model in this situation is represented in queueing using a single node, where both the customer inter-arrival time and service time follow an exponential distribution at rates $\lambda = 2$ and $\mu = 3$, respectively, as depicted in the figure.



Load the package library (queueing)

The inputs for the model were generated by creating i_mm1.<- New Input. MM1 (λ, μ) #Optionally check the inputs of the model Check-Input (i_mm1)

Create the model o_mm1 <- Queueing model (i_mm1)

Print on the screen a summary of the model print (summary (o_mm1), digits=3)

#>λ μ c k m RO $P_0 L_q W_q$ X L W $W_{qq} L_{qq}$

The output of the model includes various performance measures, such as the utilization factor (RO), probability of zero customers in the system (P_0), average number of customers in the queue (L_q), average time spent waiting in the queue (W_q), average number of customers in the system (L), average time spent in the system (W), average waiting time in the queue when a customer is present (W_{qq}), and average time spent in the system when a customer is present (L_{qq}). The functions FW_q (t) and FW(t) can also be used to view the cumulative probability distribution of the random variables w_q (time waiting) and w (time in the system) assuming FIFC as the queue discipline (Donald Gross 1974).

V. DATA INTERPRETATION AND OUTCOMES

The following table presents a summary of the number of staff arrivals, the number of staff singing in per hour, and the number of servers used. The data includes the number of staff that entered the system, the number of staff that clocked in, and the number of biometric attendance records collected during the data collection time. Please see Table 1 below for details.

Table 1: Primary Data Summary for the Randomly Selected Hours and Days via Biometric and Manual Attendance in the Year 2021

Date	Time Range (Hour)	Total Time (Hour)	No. of Staff (Arrival Rate)	No. of Servers	Biometric Attendance (Service Rate)	Manual Attendance (Service Rate)
10-Jan	9am – 10am	1:00	175	1	580	210
13-Jan	4pm – 5pm	1:00	138	1	580	210
17-Jan	4pm – 5pm	1:00	150	1	580	210
19-Jan	9am – 10am	1:00	148	1	580	210
21-Jan	9am – 10am	1:00	181	1	580	210

2-Feb	9am – 10am	1:00	145	1	580	210
5-Feb	9am – 10am	1:00	172	1	580	210
11-Feb	4pm – 5pm	1:00	151	1	580	210

The number of staff clocked-in (Arrival rate) = 157
The number of staff served within 09hr – 010hr (service rate) = 178
The number of staff (c) = 1
Total time spent in hours = 1 hr.

Mean arrival rate (λ) $= \frac{\text{arrival rate}}{\text{total time in hour}} = \frac{157}{1} = 157$

Biometric Mean Service rate $(\mu) = \frac{\text{service rate}}{\text{total time in hour}} = \frac{580}{1} = 580$

Manual Mean Service rate (μ) $= \frac{\text{service rate}}{\text{total time in hour}} = \frac{210}{1} = 210$

Results for average attendance

Total Time Involved (t)	1 hour	1 hour
Number of Staff Arrived (λ)	157	157
Number of Staff signed in/out (μ)	580	210
Number of attendance system	1	1
Model Type	m/m/1	m/m/1
Intermediate Calculation		
Performance Measures		
Rho(average server utilization),ρ	0.271	0.748
Probability of System empty, ρ_o	0.729	0.252
Average Staff in the system, L	0.37052	2.9516
Average Staff waiting in a queue, L_q	0.09952	2.2036
Average time in the system, W	0.00236	0.0188
Average time in the queue, W_q	0.000635	0.014038

VI. CONCLUSION

The queue analysis was conducted using the R programming software with observational data collected from Delhi University located inIndia. The results of the single-server-single channel queuing models for both biometric attendance and manual attendance showed a traffic intensity of 27% and 74% respectively. The traffic intensity or utilization of the biometric attendance system indicates that the system can accommodate three times the current population without getting overloaded. However, the manual attendance system requires urgent attention as it has exceeded 50% utilization, which affects the balance between server and staff. This puts staff under pressure and could potentially lead to them skipping attendance if another server is not made available.

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