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Smart Library Management System Using Face Recognition and RFID Based on Flask: Case Study of BBPPMPV BOE Malang

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ABSTRACT

This research aims to develop a Flask-based Smart Library system integrated with face recognition technology, RFID, and automated WhatsApp notifications to support library services at BBPPMPV BOE Malang. The face recognition system employs two methods: Local Binary Pattern Histogram (LBPH) and Convolutional Neural Network (CNN) for comparison. Testing results show that the LBPH method achieved a training accuracy of 98.77%, but its real-world recognition accuracy dropped to 39.77%. In contrast, the CNN method achieved a lower training accuracy of 69.11% but demonstrated more stable performance in real conditions with an average accuracy of 76.87%. RFID technology is implemented to automate the book borrowing and returning process through website integration, resulting in a time efficiency improvement of up to 74% compared to manual systems. Additionally, the system features real-time notification via WhatsApp using Venom Bot, which successfully delivers book transaction details accurately and consistently with the database records. The system is built using a Raspberry Pi 4 and the Flask framework and is accessed through a web-based interface. The implementation results show that the system significantly enhances the efficiency, security, and convenience of library services.

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1. INTRODUCTION

The rapid development of digital technology has opened up great opportunities to improve library management systems. Technology can be used to improve service quality and operational efficiency, enabling libraries to transform into modern, accessible facilities that are relevant to the needs of today's society. As centers of information and knowledge, libraries are required to continue innovating in order to maintain optimal service quality[1].

However, the library system at BBPPMPV BOE Malang still faces a number of obstacles. The process of borrowing and returning books takes a long time because it is done manually. This procedure not only makes it difficult for members but also poses security risks, such as unrecorded borrowing or unauthorized access to the library room. These issues highlight the need for innovative solutions to improve service efficiency while strengthening the security system[2].

One of the innovations developed is a smart library system that integrates Radio Frequency Identification (RFID) technology to automate the process of borrowing and returning books. With RFID, book tags can be read quickly and automatically via a web interface, reducing the risk of recording errors and saving service time. Additionally, the system is equipped with facial recognition technology to verify user identities, ensuring that only registered members can access library services[3][4].

The facial recognition technology in this system uses the Local Binary Pattern Histogram (LBPH) method as its primary method because it is fast and efficient. To enhanced user convenience, the system includes an automatic notification feature via WhatsApp that provides information regarding the status of book borrowing and returns. All activities can be monitored in real-time by administrators through a dedicated web interfaces, thereby simplifying the supervision and management of library service[5].

In addition to LBPH, this system also uses Convolutional Neural Network (CNN) as a comparison method. CNN has the ability to extract facial features more deeply, so it is expected to provide more accurate recognition results. The comparison of LBPH and CNN performance is an important basis for the development of more reliable facial recognition systems in the future. This system was built using a Raspberry Pi 4 microcontroller and the Flask framework, resulting in a modern, responsive, and user friendly service[5][6].

2. LITERATURE REVIEW

2.1 Face Recognition (LBPH and CNN)

Face recognition is one of the biometric technologies that is difficult to replicate, as each face has unique and distinct characteristics. This technology is used to identify or verify facial features in order to recognize a person's identity. It can detect a face by extracting key facial attributes, such as the distance between the eyes, the shape of the nose, the jawline contour, and other distinctive features. The extracted features are then compared with facial data stored in the database to determine whether there is a match by calculating the similarity between the input facial features and those in the database[7].

In this study, two face recognition methods were implemented: Local Binary Pattern Histogram (LBPH) and Convolutional Neural Network (CNN). Local Binary Pattern Histogram (LBPH) is a texture-based algorithm widely used for face recognition due to its efficiency and robustness under varying lighting conditions. The method works by comparing the intensity value of each pixel in a grayscale image with its surrounding pixels. Each comparison produces a binary value (0 or 1), forming a binary pattern that is later converted into a decimal number. These values are compiled into histograms representing the local texture of the face. LBPH is computationally lightweight, making it suitable for embedded systems such as the Raspberry Pi, and can deliver high accuracy in controlled environments[8][9].

Convolutional Neural Network (CNN) is a deep learning approach capable of automatically learning spatial hierarchies of features from input images. CNN architectures typically consist of convolutional layers for feature extraction, pooling layers for dimensionality reduction, and fully connected layers for classification. This method is effective at recognizing faces under various real-world conditions, such as changes in lighting, facial expressions, and orientation. However, CNN models require more computational power and longer training times compared to LBPH. By applying both LBPH and CNN, this research compares their performance to determine the most suitable method for a smart library system, balancing accuracy, stability, and system resource requirements[10][11].

2.2 Radio Frequency Identification (RFID)

Radio Frequency Identification is one of the most widely used object identification methods, particularly in the implementation of smart library systems, due to its ability to collect data automatically. RFID utilizes radio waves to identify and exchange data between an RFID tag attached to an object, such as a book, and an RFID reader device. Each RFID tag has a unique identification number, ensuring that no two RFID devices share the same ID[12].

RFID operates by using radio frequency to read information from a device known as an RFID tag. The tag is able to identify itself when it detects a signal from the RFID reader. Each object to be identified—in this case, a book—is equipped with an RFID tag, which contains a chip and an antenna that store the unique ID of the device. When the RFID reader emits radio waves, the tag responds by sending the stored data, namely the unique ID, back to the reader. This data is then read by the RFID reader and processed by the system[13].

The RFID module operates at a voltage range of 2.5 V to 3.3 V and uses a frequency of 13.56 MHz, which is a common standard for RFID systems. The module is compatible with various types of microcontrollers, such as Arduino or Raspberry Pi, making it highly versatile for integration into different automated systems, including smart libraries[14].

2.3 Framework Flask

Flask is a web framework library in the Python programming language designed for software developers and website management. It serves as a tool that helps create the structure for a web application, allowing the website to be more organized. Flask is a lightweight framework, yet it is capable of functioning effectively according to the needs of the application. It comes with several built-in features, including a built-in development server, fast debugger, RESTful request dispatching, and more[15].

3. METHODS

The research is classified as research and development (R&D), focusing on the design and implementation of a Smart Library Management System for BBPPMPV BOE Malang. The system integrates several hardware components, including a Raspberry Pi 4 as the main controller, an RFID reader for automated book borrowing and returning through the website, a webcam for face recognition, a solenoid door lock for physical access control, a 2-channel relay for controlling electronic circuits, and an LM2596 step-down converter for providing a stable power supply. These devices collectively support the smart library's core functions, enabling automation, secure access, and efficient service management. The system also incorporates automated WhatsApp notifications to inform users about borrowing and returning activities, as well as an administrative web interface for real-time monitoring. The study was conducted at the BBPPMPV BOE Malang Library in 2025, involving registered library members as the subjects and the smart library system as the research object.

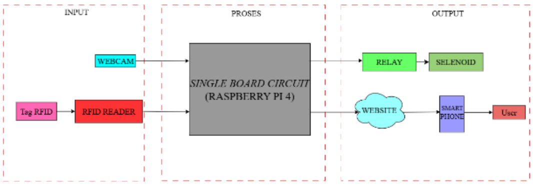

Figure 1. Block Diagram Systems

Building on the hardware configuration and system overview described in the previous paragraph, the software for the Smart Library Management System was developed using the Flask framework, featuring a web-based interface accessible to both users and administrators. To enhance access security, two face recognition methods—Local Binary Pattern Histogram (LBPH) and Convolutional Neural Network (CNN)—were implemented and compared to evaluate their performance in terms of accuracy, processing speed, and reliability under real-world conditions.

After the development and integration of the hardware and software, data collection was conducted through system implementation and direct observation. This process involved recording RFID tag readings during borrowing and returning transactions, logging face recognition results, tracking transaction records, and documenting automated WhatsApp notification activities. The collected data was then analyzed to evaluate the overall performance of the system, focusing on both the effectiveness of the face recognition algorithms and the efficiency of the web based borrowing and returning process.

4. RESULTS AND DISCUSSION

4.1 Local Binary Pattern Histogram Accuracy

Based on Figure 2, the training process achieved an average accuracy of 98.77%. Face recognition recorded an average accuracy of 39.77% across various facial expressions in front, left, and right positions (Table 1). LBPH results (Figure 4.43) indicated the highest accuracy of 58.07% for "Wahyu" in the left position with a pouting expression, while both users performed better in the front position. The lowest accuracy, 0%, occurred in certain left or right positions with neutral or smiling expressions. Overall, "Wahyu" demonstrated higher accuracy than "Ambar" in side positions recorded 0% accuracy. Overall, user "Wahyu" demonstrated higher accuracy than "Ambar" in side positions.

Table 1. LBPH Accuracy Data

Name	Position	Expression	Accuracy (%)
Ambar	Front	Neutral	48,56
		Smiling	50,03
		Pouting	47,9
		Grimacing	45,15
		Blinking	43,71
	Left	Neutral	- (No Frame)
		Smiling	41
		Pouting	- (No Frame)
		Grimacing	39,17
		Blinking	43,61
	Right	Neutral	- (No Frame)
		Smiling	- (No Frame)
		Pouting	48,56
		Grimacing	50,03
		Blinking	47,9
Wahyu	Front	Neutral	44,52
		Smiling	53,24
		Pouting	53,45
		Grimacing	43,23
		Blinking	55,38
	Left	Neutral	47,02
		Smiling	50
		Pouting	58,07
		Grimacing	50,65
		Blinking	51,25
	Right	Neutral	- (No Frame)
		Smiling	48,88
		Pouting	47,02
		Grimacing	36,43
		Blinking	48,63

From the test results shown in the diagram in Figure 2, it is evident that LBPH performance exhibits high variability depending on the individual and the training dataset. The LBPH method demonstrates varying performance depending on the individual, facial position, and expression. LBPH is highly sensitive to changes in facial pose and expression, as well as to variations in lighting. This occurs because, in right or left positions, parts of the face may not be well illuminated in front of the camera. This indicates that facial position affects accuracy results in addition to the influence of facial expression parameters. Therefore, users are advised to perform face recognition in a straight-ahead position with a neutral or smiling expression to enable the system to detect and recognize faces with better results.

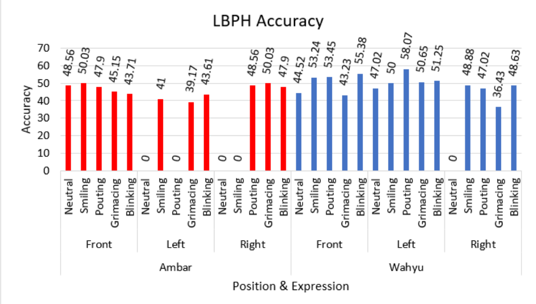

Figure 2. LBPH Accuracy

4.2 *Convolutional Neural Network Accuracy*

Based on the testing results in Figure 3, the training process achieved an average accuracy of 69.11%. Meanwhile, in face recognition, the average accuracy across various facial expressions with straight front, left, and right positions, as shown in Table 2, was 76.87%. The CNN accuracy test results are represented as percentages, with red bars for user "Ambar" and blue bars for user "Wahyu" in Figure 3. The highest accuracy was obtained in the straight front position, with an average accuracy of 83.11% for user "Ambar" and 83.02% for user "Wahyu." In terms of facial expressions, the highest accuracy for user "Ambar" was recorded in the straight front position with a neutral expression at 88.22%, while for user "Wahyu," it was in the smiling expression at 86.64%. The lowest accuracy was found in the left position with a grimacing expression, achieving 64.72% for user "Ambar," while for user "Wahyu," it was in the right position with a blinking expression at 68.77%.

Table 2. CNN Accuracy Data

Name	Position	Expression	Accuracy (%)
Ambar	Front	Neutral	88,22
		Smiling	78,96
		Pouting	81,76
		Grimacing	83,40
		Blinking	83,22
	Left	Neutral	73,83
		Smiling	74,83
		Pouting	70,87
		Grimacing	64,87
		Blinking	66,87
	Right	Neutral	76,92
		Smiling	77,52
		Pouting	74,57
		Grimacing	77,89
		Blinking	64,72
Wahyu	Front	Neutral	83,61
		Smiling	86,64
		Pouting	82,86
		Grimacing	74,60
		Blinking	87,51
	Left	Neutral	74,41
		Smiling	80,39
		Pouting	73,51
		Grimacing	82,13
		Blinking	68,90
	Right	Neutral	82,29
		Smiling	78,21
		Pouting	70,13
		Grimacing	73,72
		Blinking	68,77

From the test results shown in the diagram in Figure 3, it is evident that variations in facial expression and position affect the resulting accuracy. The straight-ahead position yields the highest accuracy, while right or left tilted positions produce lower accuracy because some facial landmarks are not captured by the camera. Facial expressions can also alter the positions of facial landmarks, which can cause variations in the facial embeddings generated by the CNN model, resulting in less consistent similarity measurements. Therefore, the greater the variation in facial expressions and positions, the higher the likelihood of a decrease in face recognition accuracy. For this reason, users are advised to perform face recognition in a straight-ahead position with a neutral expression so that the system can detect and recognize faces with better results.

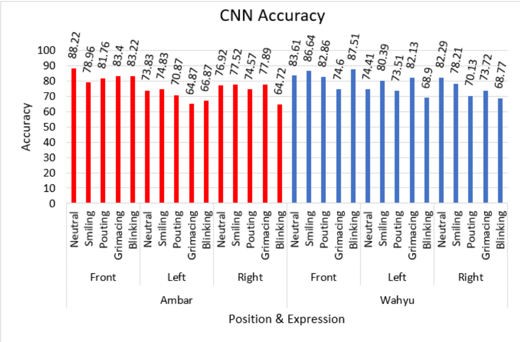

Figure 3. CNN Accuracy

4.3 *efficiency of the book lending system*

Table 3. Borrowing Duration Comparison between Manual and RFID Methods.

No	Borrower Name	Method	Duration (s)
1.	Dita Fitriana	Manual	95
		RFID	20
2.	Wahyu Nur Anggoro Wati	Manual	90
		RFID	24
3.	M. Fauzan Ardika Akbar	Manual	100
		RFID	20
4.	Rangga Nurdiansyah	Manual	90
		RFID	22
5.	Nazwa Ayunda	Manual	92
		RFID	27
6.	Lintang Apriliya	Manual	88
		RFID	25
7.	Gusson Iqbal Maulana	Manual	93
		RFID	28
8.	Devannes Agastama Erkan Putra	Manual	98
		RFID	25
9.	Chandra Widya Surya Pratama	Manual	95
		RFID	22
10.	Martanti Puri Rahayu	Manual	90
		RFID	20

Based on the test results in Table 3, the average time required for the manual system is 93 seconds, whereas the Smart Library system using RFID technology for automation requires only 24 seconds. The results indicate an average time savings of 74% compared to the manual method. This demonstrates that the implementation of an automated system with RFID technology is more efficient in supporting library operations, especially during peak hours or when there are long queues of book borrowers.

5. CONCLUSION

The development of a Smart Library System at BBPPMPV BOE Malang successfully combined face recognition and RFID technologies to enhance efficiency and security. Testing showed that the LBPH method achieved high training accuracy (98.77%) but dropped to 39.77% in real conditions, while CNN maintained greater stability with 69.11% training accuracy and 76.87% in real recognition, making CNN more adaptive to variations in expression and lighting. RFID implementation significantly improved book borrowing and returning efficiency, reducing transaction time from an average of 93 seconds manually to 24 seconds, achieving a 74% time saving, particularly beneficial during peak hours. Furthermore, the system integrated real-time WhatsApp notifications for borrowing transactions via Venom Bot, ensuring accurate and consistent information delivery to users.

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