IJEEMCS : International Journal of Electrical Engineering, Mathematics and Computer Science
Vol. 1, No.4 December 2024
e-ISSN: 3048-1945, p-ISSN : 3048-1910, Page 16-26
DOI: https://doi.org/10.62951/ijeemcs.v1i4.108
Available online at: https://international.arteii.or.id/index.php/IJEEMCS

Development of Hand Gesture Detection Application for Slap Mosquito Game Based on Image Processing

Rajhaga Jevanya Meliala [1*], Nur Indah Chasanah [2], Jonser Steven Rajali Manik [3], Anggito Rangkuti Bagas Muzaqi [4], Syah Bintang [5], Endang Purnama Giri [6], Gema Parasti Mindara [7]
[1-7] IPB University, Indonesia

Address: Kumbang Street No. 14, Bogor - West Java 16128
Corresponding author : rajhaga7jevanya@apps.ipb.ac.id *

Abstract. *The development of technology with digital image processing is often utilized to solve various problems in image processing, such as facial recognition, object detection, and interaction between users. In this study, we developed an interactive hand gesture-based game titled "Slap Mosquito" that utilizes image processing techniques to control the game through hand gestures. Using Rapid Application Development (RAD), Python, OpenCV, and Pygame methodologies, this game allows users to slap mosquitoes virtually in real-time through hand gesture recognition that is read by the camera and translated into in-game actions. RAD allows rapid development iterations and improvements based on user feedback, which is essential for improving system responsiveness and accuracy. This study focuses on detection precision, system responsiveness, and the impact of lighting on game performance, as measured using frames per second (FPS) and user gameplay results. The test results show that optimal lighting meets high detection accuracy, while low lighting conditions have a negative impact on accuracy and responsiveness. The results of this study provide insights for further development of gesture-based applications, especially regarding the importance of optimizing technical parameters and RAD methodology in improving user experience.*

Keywords *Hand Gesture Recognition, Image Processing, Rapid Application Development (RAD), Detection Accuracy, System Responsiveness*

1. BACKGROUND

The development of technology through digital image processing is frequently utilized to address various issues in image processing, such as facial recognition, object detection, and user interaction with applications, as in the game "Slap Mosquito" (Farida 2023). This application can capture gestures with precise accuracy in various lighting and environmental conditions, providing real-time responses. Real-time gesture recognition is employed to interpret the meaning behind human movement expressions, including hand, facial, head, or body gestures. Hand gesture recognition facilitates easier interaction with computers (Wu et al., 2021) by using digital image processing, a technique used to manipulate and analyze images captured from the real world. This approach aims to identify essential features from images or videos that capture hand gestures and to improve the accuracy of gesture recognition(Al Farid et al., 2022).

Received Oktober 20, 2024; Received Oktober 28, 2024; Accepted November 09 2024; Online Available November 15 2024

Previous research utilizing digital image technology has primarily focused on static images rather than real-time motion images (Fadhliana et al., 2022). Creating real-time objects requires enhancing communication functions that relay hand gestures to the camera. In detecting hand movements, the system can interpret these as actions within the game (Oudah et al., 2020). Previous studies have also produced hand-detection applications by combining images, thus enhancing user interaction through a first-person view perspective in gaming (Mujahid et al., 2021). Consequently, this study will discuss the application of digital image processing technology using the Rapid Application Development (RAD) methodology to enable real-time hand gesture detection (Wulandari et al., 2020). This research contributes digital image processing technology to create a more dynamic interaction for users through a visual-based system. It leverages real-time hand gesture detection, processing these gestures to provide responses aligned with gameplay.

2. LITERATURE REVIEW

In the study titled "Analisis Perbandingan Algoritma Machine Learning Dan Deep Learning Untuk Klasifikasi Citra Sistem Isyarat Bahasa Indonesia (SIBI)" hand gesture recognition features were analyzed using static images of Indonesian Sign Language (SIBI) with algorithms such as Naive Bayes, KNN, Neural Network, SVM, and C4.5. The researchers explored how various features, including distance, angle, and quadrant of the hand, could influence gesture recognition accuracy. The dataset used consisted of 528 hand images, and testing was conducted using K-fold cross-validation to determine the highest accuracy. The results indicated that a combination of distance, angle, and quadrant features achieved up to 60% accuracy in gesture recognition on the dataset (Naufal et al., 2023).

Using the RAD Method

The study titled "Pengembangan Sistem Pendeteksi Gesture Angka pada Tangan secara Realtime Berbasis Android" developed an Android application for real-time number gesture detection. This application used the Rapid Application Development (RAD) method to accelerate the development and testing process. Color segmentation and morphological techniques were employed to enhance detection accuracy, aiming to assist communication for individuals with hearing disabilities who use hand gestures. The findings demonstrated that color segmentation improved detection accuracy, although challenges remained in adapting to dynamic lighting and background conditions (Wulandari et al. 2020).

Real-Time Hand Gesture Recognition

In the study "Hand Gesture Detection Based on Image Processing," the YOLO-v3 algorithm was used for real-time hand gesture detection under various lighting and background conditions. YOLO-v3 is known for its fast object detection capabilities, and this study showed that the system could detect and classify hand gestures with over 90% accuracy. These results underscore the relevance of YOLO-v3 in applications requiring fast and accurate detection, such as gesture-based games and other human-computer interaction systems focused on image processing (Sani & Rahmadinni 2022).

Hand Gesture Recognition in HCI

The study titled “Methods, Databases and Recent Advancement of Vision-Based Hand Gesture Recognition for HCI Systems: A Review”,discusses computer vision-based hand gesture recognition for HCI applications such as sign language and VR/AR. Two main approaches are physical sensors on the hand and image/video-based recognition. The focus is on computer vision, covering stages such as acquisition, detection, feature extraction, and classification with deep learning. This paper also includes databases and recent developments to support further research in this field (Sarma & Bhuyan 2021).

3. METHODS

The design of the Slap Mosquito system in this study consists of two main activities, data acquisition and data processing. Data acquisition is performed through a camera to detect hand movements, while data processing uses image processing techniques integrated with a specific framework to generate an interactive game response. Rapid Application Development (RAD) is a suitable method for games like Slap Mosquito, as it allows for fast iteration, direct feedback from users, and a focus on functional prototypes (Fergina, Sujjada, and Alviqih 2023). RAD emphasizes a cyclical approach in software development by actively involving users with short and rapid development cycles. Time efficiency is a crucial constraint in this model (Rusmawan 2022). The following outlines the utilization of the RAD method and the integration of gesture recognition in the system development stages.

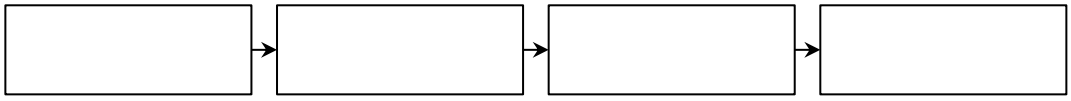

Figure 1. Stages of The RAD Method.

Rapid Application Development (RAD) is a software development method that emphasizes speed and flexibility, with rapid iterations and direct feedback from users. This

method divides the process into planning, prototyping, testing, and implementation, allowing for dynamic feature adjustments based on user needs (Utami et al., 2023).

Feature Selection

The features incorporated in the Slap Mosquito game include Leaderboard, Double Point, Boss Fight, Hand Detection, Slap Hand, and -1 Point.

1. **Leaderboard Feature**

This feature displays rankings and the highest scores achieved by players. Additionally, the leaderboard aims to motivate players to improve their scores and compete for the top positions.

2. **Double Point Feature**

This feature enables players to earn double points within a set timeframe. When Double Point is active, each mosquito successfully slapped yields two points. The double-point feature also allows players to boost their scores quickly.

3. **Boss Fight Feature**

This feature is triggered by the appearance of a larger-than-usual mosquito, adding an extra challenge. Players earn additional points after defeating the boss mosquito.

4. **Hand Detection Feature**

This feature leverages image processing technology to detect hand movements, allowing players to interact with the game by simply showing their palm to the camera.

5. **Slap Hand Feature**

This feature allows players to perform a slap motion to eliminate mosquitoes appearing on the screen. The objective is to accumulate as many points as possible.

6. **-1 Point Feature**

This feature introduces an element of risk to the game. If players mistakenly slap a bee, they lose one point. This feature encourages players to be cautious with each movement.

Data Collection

The data processing phase employs image processing techniques integrated with a framework to transform visual data into interactive game responses, enhancing player engagement through real-time interactivity.

Data Processing

The hand and landmark detection stage utilizes MediaPipe or OpenCV to detect hand points, such as fingertips, in real-time (Budiman et al., 2022), enabling rapid interaction within HCI applications. The segmentation stage separates the hand from the background by comparing each new frame with the initial frame to detect changes. In the Feature Extraction

stage, the system identifies the edges and corners of the hand from grayscale images to recognize specific gestures. Finally, the Integration with Game stage links hand movement data to actions in PyGame, allowing players to interact through gestures, such as catching mosquitoes or activating features swiftly (Saputra & Hariyanto, 2024).

4. RESULTS

The research results were obtained from testing the Slap Mosquito application developed using gesture-based image processing technology to test the effectiveness of hand gesture detection in real-time interaction within the game application. The results include accuracy, responsiveness of the application, and the impact of lighting conditions on overall performance. The data obtained from testing, such as gesture detection accuracy, player game results, and frames per second (FPS), are presented in tables and graphs to provide a visual representation of the application's performance.

Application Implementation

After pressing the "START" button on the intro page, users will be directed to a page to enter their username.

Figure 2. Display The Game Start Page.

After entering the username, the user will immediately enter the Slap Mosquito game. Here, the user will face the challenge of catching the mosquitoes that appear on the screen using hand gestures.

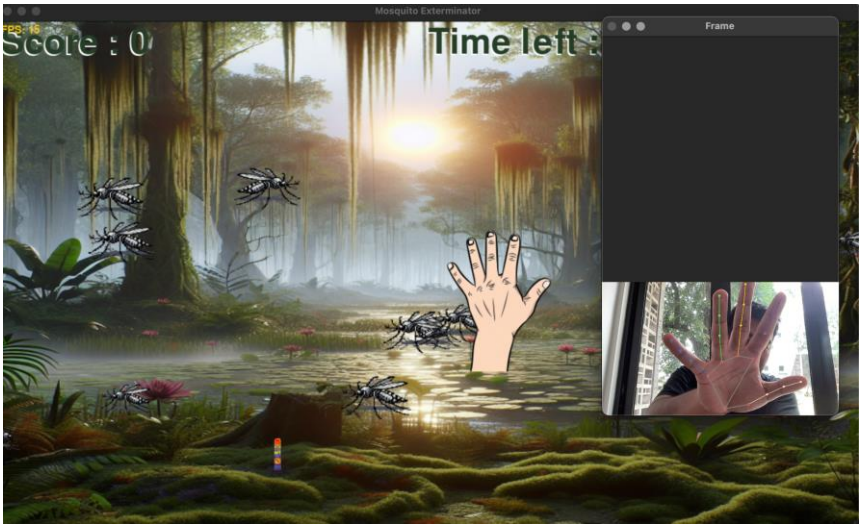

Figure 3. Recognition of Hand Gestures in Games.

In the middle of the Slap Mosquito game, an additional challenge in the form of a boss will appear. Players must defeat this boss to earn bonuses, such as additional playtime. This not only increases the excitement of the game but also gives players the opportunity to achieve higher scores.

Figure 4. Monster Battle Screen.

Impact of Webcam

Data collection using the webcam is highly dependent on lighting conditions and the environment. The FPS Performance over Frames graph shows fluctuations in FPS (frames per second), indicating that the system's performance is inconsistent over time. These unstable FPS rates may occur due to several factors, including lighting quality and other applications running on the device while the game is being played.

The FPS performance analysis in the Slap Mosquito game was conducted to assess the stability of the application's performance under various lighting conditions and the load from

other running applications. This study covers three main conditions: bright light with no other applications open, bright light with other applications running, and low or dark lighting.

In the first condition, bright light with no other applications running, the system shows optimal performance with stable FPS ranging from 15-20 FPS after the initial frames. This stability in FPS shows that the application runs responsively, as device resources are allocated solely to the game without competition from other applications. Additionally, good lighting helps the system detect hand movements, as the difference between the hand and background can be clearly captured by the camera. In this condition, the game runs smoothly, providing a comfortable gaming experience for users.

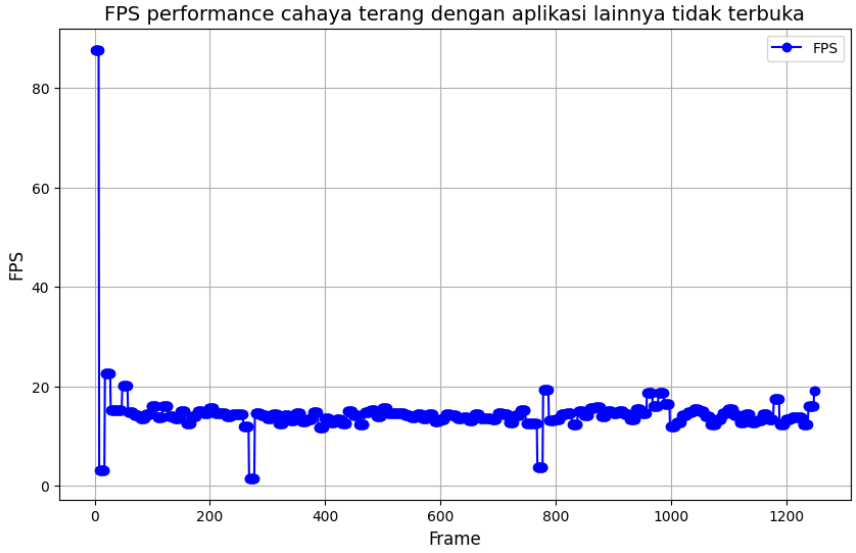

Figure 5. Performance Graphics 15-20 FPS.

In contrast, under low or dark lighting conditions, the application performance shows significant FPS fluctuations. When lighting decreases, many frames experience a drastic drop in FPS, indicating that the system takes more time to process the visual data. Poor lighting makes it difficult for the system to segment and detect hand movements, as it has to work harder to separate the hand from the less visible background. This results in slower response times during gameplay and can cause users to experience lag, leading to a suboptimal gaming experience. Thus, adequate lighting is crucial for maintaining FPS stability and ensuring smooth gameplay.

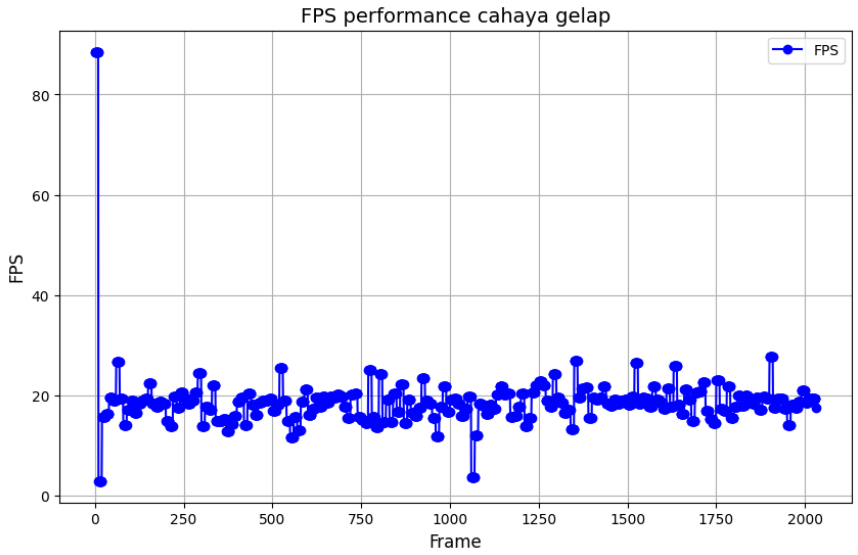

Figure 6. FPS Graph under Dark Lighting.

In the final condition, where the lighting is adequate but other applications are running in the background, the FPS performance remains fairly stable but with more frequent fluctuations compared to the condition with no other applications open. In this situation, the FPS slightly decreases periodically due to competition for device resources between the Slap Mosquito game and other running applications. The presence of other applications causes CPU and RAM resources to be divided, reducing the system's ability to process hand gesture data as efficiently as when no other applications are open. Nonetheless, performance remains within an acceptable range, though with more frequent FPS drops, which can slightly affect the gaming experience.

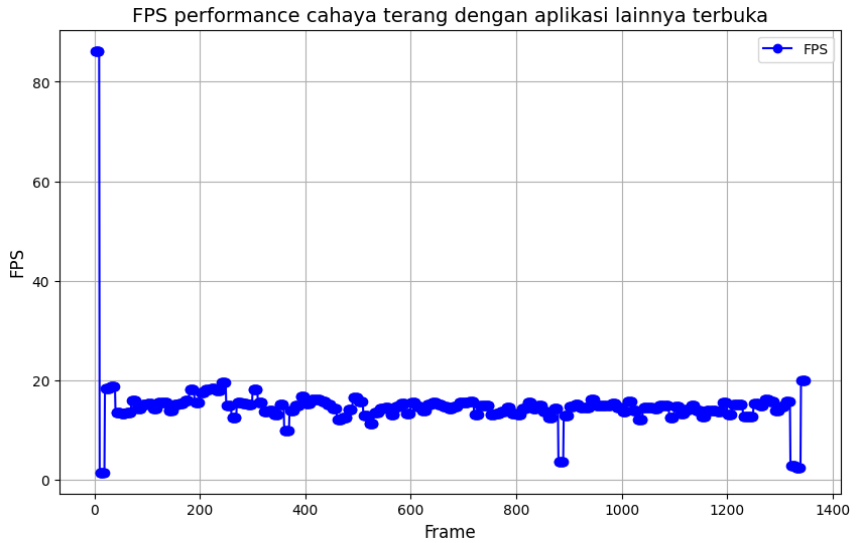

Figure 7. FPS Graph under Adequate Lighting.

The results of this analysis suggest that the optimal condition for playing Slap Mosquito is with adequate lighting and no other applications running in the background. This condition allows for more accurate hand gesture detection and better FPS stability, ensuring a responsive and uninterrupted gaming experience. Conditions with low lighting or running background applications may cause a decrease in performance, so it is recommended for users to ensure optimal lighting and minimize open applications during gameplay.

5. CONCLUSION

This study demonstrates the effectiveness and practicality of using digital image processing for hand gesture recognition in interactive games, as illustrated by the development of the "Slap Mosquito" game. Employing the Rapid Application Development (RAD) methodology proved advantageous, allowing for quick iterations and refinements based on user feedback. Various tests highlighted that optimal lighting conditions are crucial for maintaining high accuracy and system responsiveness, significantly enhancing gesture recognition clarity and improving the overall user experience.

Under bright lighting conditions and without other applications running on the device, the game achieved stable frames per second (FPS) and minimized lag, leading to smooth, responsive gameplay. In contrast, low lighting and running additional applications caused a noticeable drop in performance, resulting in FPS fluctuations and reducing the game's responsiveness.

Insights gained from this research emphasize the importance of environmental and technical considerations, such as lighting and device load, in enhancing accuracy and user experience in gesture-based applications. Findings offer valuable guidance for future advancements in real-time gesture-based games and other human-computer interaction (HCI) applications. Further optimization of image processing parameters and exploration of robust algorithms are recommended to advance responsiveness and adaptability of gesture recognition technology under diverse conditions.

REFERENCES

Al Farid, Fahmid, Noramiza Hashim, Junaidi Abdullah, Md Roman Bhuiyan, Wan Noor Shahida Mohd Isa, Jia Uddin, Mohammad Ahsanul Haque, and Mohd Nizam Husen. 2022. "A Structured and Methodological Review on Vision-Based Hand Gesture Recognition System." *Journal of Imaging* 8(6):153. doi: 10.3390/jimaging8060153.

Budiman, Saiful Nur, Sri Lestanti, Suji Marselius Evvandri, and Rahma Kartika Putri. 2022. "PENGENALAN GESTUR GERAKAN JARI UNTUK MENGONTROL VOLUME DI KOMPUTER MENGGUNAKAN LIBRARY OPENCV DAN MEDIAPIPE." *Antivirus : Jurnal Ilmiah Teknik Informatika* 16(2):223–32. doi: 10.35457/antivirus.v16i2.2508.

Fadhliana, Nisa Rizqiya, Yunita Putri Arinda, and Eny Maria. 2022. "Perancangan Aplikasi Virtual Tour Program Studi TRPL Di Politani Samarinda Berbasis Hand Motion Tracking." *Jurnal Sains Dan Informatika* 8(1):1–10. doi: 10.34128/jsi.v8i1.343.

Farida, Lufiatul. 2023. "KOMPARASI METODE DETEKSI TEPI DENGAN METODE SOBEL DAN PREWITT PADA PENGOLAHAN CITRA DAUN." *Jurnal Teknologi Pintar* 3(10).

Fergina, Anggun, Alun Sujjada, and Fadillah Alviqih. 2023. "Implementasi Sistem Informasi Akademik Menerapkan Metode Rapid Application Development." *KLIK: Kajian Ilmiah Informatika Dan Komputer* 3(6):1310–19. doi: 10.30865/klik.v3i6.854.

Mujahid, Abdullah, Mazhar Javed Awan, Awais Yasin, Mazin Abed Mohammed, Robertas Damaševičius, Rytis Maskeliūnas, and Karrar Hameed Abdulkareem. 2021. "Real-Time Hand Gesture Recognition Based on Deep Learning YOLOv3 Model." *Applied Sciences* 11(9):4164. doi: 10.3390/app11094164.

Naufal, Mohammad Farid, and Selvia Ferdiana Kusuma. 2023. "Analisis Perbandingan Algoritma Machine Learning Dan Deep Learning Untuk Klasifikasi Citra Sistem Isyarat Bahasa Indonesia (SIBI)." *Jurnal Teknologi Informasi Dan Ilmu Komputer (JTIIK)* 10(4):873–82.

Oudah, Munir, Ali Al-Naji, and Javaan Chahl. 2020. "Hand Gesture Recognition Based on Computer Vision: A Review of Techniques." *Journal of Imaging* 6(8):73. doi: 10.3390/jimaging6080073.

Rusmawan, Uus. 2022. "Sistem Informasi Koperasi Menggunakan Metode Rapid Application Development (RAD)." *Journal of Information System and Technology* 1(1):1–10. doi: 10.56916/jistec.v1i1.80.

Sani, Abdullah, and Suci Rahmadinni. 2022. "Deteksi Gestur Tangan Berbasis Pengolahan Citra." *Jurnal Rekayasa Elektrika* 18(2). doi: 10.17529/jre.v18i2.25147.

Saputra, Windi, and Susanto Hariyanto. 2024. "IMPLEMENTASI HAND GESTURE MEDIAPIPE PADA GAME INTERAKTIF UNTUK STIMULASI MOTORIK ANAK DOWN SYNDROME PADA SEKOLAH LUAR BIASA AUTIS KALIMANTAN BARAT." *JATI (Jurnal Mahasiswa Teknik Informatika)* 8(5):10776–84. doi: 10.36040/jati.v8i5.11127.

Sarma, Debajit, and M. K. Bhuyan. 2021. "Methods, Databases and Recent Advancement of Vision-Based Hand Gesture Recognition for HCI Systems: A Review." *SN Computer Science* 2(6):436. doi: 10.1007/s42979-021-00827-x.

Utami, Ersi Putri, and Afrizal Zein. 2023. "Perancangan Sistem Informasi Reservasi Meja Kafe Menggunakan Metode Rad Rapid Application Development Berbasis Web (Studi

Kasus : Cafetaria Citra Sawangan Depok).” *Engineering and Technology International Journal* 5(02):108–16. doi: 10.55642/eatij.v5i02.346.

Wu, Bi-Xiao, Chen-Guang Yang, and Jun-Pei Zhong. 2021. “Research on Transfer Learning of Vision-Based Gesture Recognition.” *International Journal of Automation and Computing* 18(3):422–31. doi: 10.1007/s11633-020-1273-9.

Wulandari, Pradipta Sekar Ayu Putri, Kurniawan Teguh Martono, and Ike Pertiwi Windasari. 2020. “Pengembangan Sistem Pendeteksi Gesture Angka Pada Tangan Secara Realtime Berbasis Android.” *Edu Komputika Journal* 7(1):1–9. doi: 10.15294/edukomputika.v7i1.38655.