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IMPLEMENTATION OF GEOFENCING ALGORITHM FOR MOBILE-BASED ONLINE STUDENT ATTENDANCE SYSTEM AT SMA NEGERI 5 MEDAN

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ABSTRACT

The manual attendance system still used in many schools has significant weaknesses such as time inefficiency, vulnerability to "proxy attendance" manipulation, and human error in the recapitulation process. This research aims to develop a mobile-based student attendance system with Geofencing technology using the AABB (Axis-Aligned Bounding Box) algorithm to ensure the validity of student attendance only within predetermined school areas. The research method employs a Prototyping approach with a technology stack consisting of Flutter for the frontend, Laravel for the backend API, MySQL and Firebase Realtime Database for data storage, and Mapbox API for 3D map visualization. The novelty of this research lies in the implementation of a 3D volumetric virtual fence that validates not only horizontal coordinates (latitude and longitude) but also the vertical altitude of students, addressing manipulation vulnerabilities present in conventional 2D Geofencing systems. Functional testing results (black box testing) demonstrate that all main system features operate according to specifications for the three user roles (Administrator, Teacher, and Student). Geofencing accuracy testing proves that the AABB algorithm is capable of validating locations with a 100% success rate across various test scenarios, including rejection of attendance attempts from outside the configured horizontal and vertical boundaries. Compatibility testing on 20 Android devices shows that the application runs stably with good location accuracy. This system successfully enhances attendance process efficiency, attendance data accuracy, and significantly prevents location manipulation. The implementation of Firebase Realtime Database enables real-time attendance monitoring by teachers, while the Mapbox 3D-based visual interface facilitates Administrator configuration of validation areas. This research *provides an important contribution to the development of Location-Based Services (LBS) systems for the education sector through a three-dimensional spatial validation approach.*

INTRODUCTION

In the era of educational digitalization, schools are required to manage administrative processes quickly, accurately, and efficiently (Gupta & Kumar, 2021). One administrative activity with a high level of complexity is the management of student attendance data. This activity is conducted daily, involving hundreds of students and dozens of classes, thus generating large and repetitive data transaction volumes. Manual management through roll calls and signatures not only consumes teachers' time at the beginning of learning sessions but also adds to the administrative burden in daily to monthly recapitulation processes (Tresnani, Lestari, & Rinaldi, 2012).

SMA Negeri 5 Medan, as an educational institution with a large student population, faces similar challenges. The massive attendance data processing requires a system capable of automating data recording and validation quickly, accurately, and resource efficiently. The implementation of mobile technology becomes a potential solution, as mobile devices have now become a common tool for students and teachers (Santoso, Suharso, & Hariyady, 2022). However, conventional online attendance systems still leave location validation problems students can perform attendance from outside the school area as long as the device is connected to the internet.

To address this issue, Geofencing technology can be applied as a GPS coordinate-based location verification mechanism. By building a virtual fence around the school area, the system will only accept attendance from devices that are actually within the predetermined zone. Previous research has implemented Geofencing for attendance systems, but the majority remain limited to 2D (horizontal) validation using methods such as the Haversine Algorithm or conventional 2D Geofencing (Sudirman, Susatyono, & Azhari, 2025).

The research gap identified is the absence of altitude validation in these systems, which allows vertical location manipulation from tall buildings around the school that still fall within the radius or polygon of the 2D fence. Therefore, this research proposes the implementation of 3D volumetric Geofencing using the AABB (Axis-Aligned Bounding Box) algorithm that validates not only horizontal coordinates (latitude, longitude) but also the altitude of students within a predetermined 3D volume (Ericson, 2004).

RESEARCH METHODS

System Development Method

This research employs the Prototyping method, which was selected because it enables iterative system development with user involvement from the early stages (Pressman & Maxim, 2023). The Prototyping model consists of five main stages: communication, rapid planning, modeling, construction, and delivery to users. This approach is highly suitable for research focusing on the implementation and validation of new concepts such as 3D Geofencing.

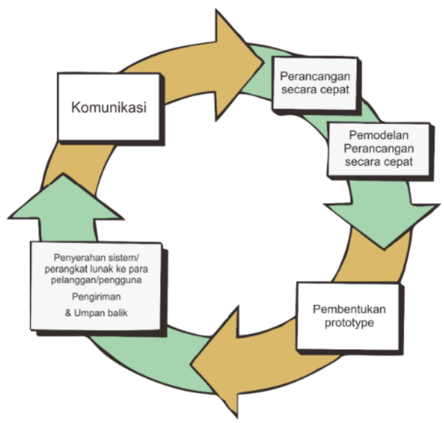

Figure 1. Prototyping Method Flow

The figure shows an iterative cycle from the communication stage to system delivery to users with a feedback mechanism for improvement.

Data Collection

Data collection was conducted through three methods:

1. Literature Study: Review of textbooks, official technical documentation, scientific articles, and relevant publications about Geofencing, AABB algorithm, Flutter and Laravel frameworks, and Firebase Realtime Database.
2. Observation: Direct observation of the manual attendance process at SMA Negeri 5 Medan to identify inefficiencies, human errors, and potential manipulation.
3. Interviews: Semi-structured interviews with teachers and administrative staff to understand system requirements and challenges faced.

System Requirements Analysis

System requirements are classified into two categories:

A. Functional Requirements

For Administrator:

- Authentication and master data management (students, teachers, classes, schedules)

- Configuration of 3D virtual fence area boundaries (6 AABB parameters)
- System monitoring and recapitulation reports

For Teachers:

- Class session management (starting/ending attendance)
- Real-time student attendance monitoring
- Manual attendance input and per-class reports

For Students:

- Authentication and schedule display
- Attendance recording (check-in) with 3D location validation
- Personal attendance history

B. Non-Functional Requirements

- Performance: Validation response time < 5 seconds
- Security: Secure authentication and role-based access control
- Usability: Intuitive and user-friendly interface
- Reliability: High availability during operational hours
- Compatibility: Runs on Android API 28+

System Design

System Architecture

The system is designed using a layered architecture involving:

- Frontend Admin (Flutter Mobile)
- Backend API (Laravel)
- Database (MySQL for persistent data, Firebase Realtime Database for real-time data)
- Mapbox API (3D map visualization)

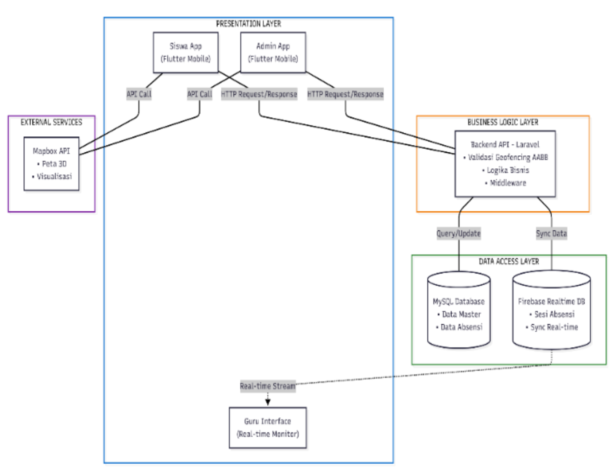

Figure 2. Geofencing-Based Attendance System Architecture

The diagram shows the interaction between frontend components, backend, database, and third-party services.

Database Design

The relational database (MySQL) is designed with main entities: admins, teachers, students, school_classes, subjects, schedules, attendances, and settings. The settings table stores 6 AABB boundary values for 3D Geofencing configuration.

Table 1. Settings Table Structure for 3D Geofencing Parameter

No	Field	Data Type	Description
1	geofence_max_lat	DECIMAL(10,7)	Maximum latitude boundary
2	geofence_min_lat	DECIMAL(10,7)	Minimum latitude boundary
3	geofence_max_lon	DECIMAL(11,7)	Maximum longitude boundary
4	geofence_min_lon	DECIMAL(11,7)	Minimum longitude boundary
5	geofence_max_alt	DECIMAL(10,2)	Maximum altitude boundary (meters)
6	geofence_min_alt	DECIMAL(10,2)	Minimum altitude boundary (meters)

Firebase Realtime Database is used to store real-time attendance status with the path structure: /sessions/{schedule_id}/{student_id}.

UML Modeling

The system is modeled using Use Case Diagrams, Sequence Diagrams, Class Diagrams, and Activity Diagrams to illustrate user interactions, process flows, and data structure.

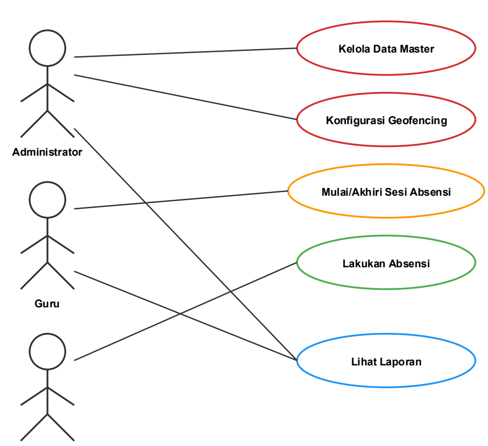

Figure 3. System Use Case Diagram

The diagram shows three main actors (Administrator, Teacher, Student) and their respective use cases.

Implementation of AABB 3D Algorithm

The AABB (Axis-Aligned Bounding Box) algorithm is implemented to validate student location within a 3D volume. The validation process is performed by comparing student coordinates (latitude, longitude, altitude) against 6 configured boundaries.

AABB Algorithm Pseudocode:

```
FUNCTION checkGeofenceAABB(studentLat, studentLon, studentAlt):
    // Retrieve 6 boundary parameters from database
    maxLat = getSetting('geofence_max_lat')
    minLat = getSetting('geofence_min_lat')
    maxLon = getSetting('geofence_max_lon')
    minLon = getSetting('geofence_min_lon')
    maxAlt = getSetting('geofence_max_alt')
    minAlt = getSetting('geofence_min_alt')

    // AABB 3D Validation
    isInsideVolume = (
     studentLat <= maxLat AND
     studentLat >= minLat AND
     studentLon <= maxLon AND
     studentLon >= minLon AND
     studentAlt <= maxAlt AND
     studentAlt >= minAlt
     )

      RETURN isInsideVolume
    END FUNCTION
```

This algorithm has a time complexity of O(1) because it only involves 6 simple comparisons, making it highly efficient for real-time systems (Ericson, 2004).

System Testing

Testing was conducted through three methods:

1. Functional Testing (Black Box): Verifying all system features according to specifications for the three user roles.
2. 3D Geofencing Accuracy Testing: Validating the AABB algorithm with various location scenarios (inside volume, outside horizontal boundaries, outside vertical

boundaries).

3. Compatibility Testing: Testing the application on 20 Android devices with variations in brands and OS versions (Android 9-14).

RESULTS AND DISCUSSION

System Implementation

The system was successfully implemented with the following components:

Backend API (Laravel)

- MVC structure with Eloquent ORM
- RESTful API endpoints with authentication middleware
- Firebase SDK integration for real-time data push
- Implementation of checkGeofenceRectangular() function that executes 3D AABB logic

Administrator Frontend (Flutter)

- Mapbox Maps SDK integration with 3D visualization
- Configuration form for 6 AABB parameters with real-time visual updates
- CRUD features for master data management
- Structured state management

3D Geofencing Visualization

The administrator interface provides interactive 3D volume visualization using Mapbox FillExtrusionLayer. Administrators can input 6 AABB boundary values through a form, and the system automatically displays a visual representation of the volume on the map.

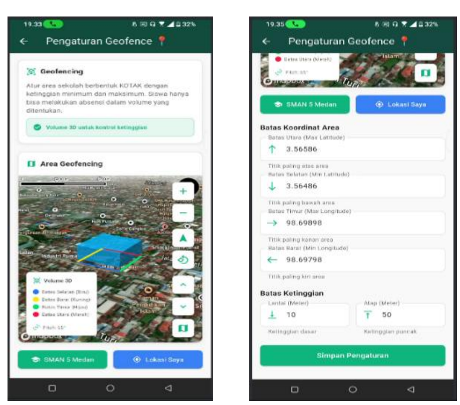

Figure 4. 3D Geofencing Configuration Interface

The display shows a 3D Mapbox map with an AABB volume that can be configured through the input form below it.

Testing Results

A. Functional Testing (Black Box)

Testing was conducted on 29 scenarios covering features for Administrators (13 scenarios), Teachers (7 scenarios), and Students (9 scenarios).

Table 2. Summary of Functional Testing Results

Role	Total Scenarios	Successful	Percentage
Administrator	13	13	100%
Teacher	7	7	100%
Student	9	9	100%
Total	29	29	100%

The results show that all main system features operated according to specifications, including:

- Authentication for all roles
- Master data management (CRUD)
- 3D Geofencing configuration and updates
- Attendance session management by teachers
- Real-time monitoring through Firebase
- Student check-in process with AABB validation
- Attendance report generation

B. 3D Geofencing Accuracy Testing

Testing was conducted with 5 scenarios to validate the AABB algorithm:

Table 3. 3D Geofencing Accuracy Testing Results

No	Komponen Pengujian	Lokasi Uji (Latitude, Longitude, Altitude)	Hasil Diharapkan	Hasil Aktual Sistem	Nilai	
					Sesuai	Tidak
1	Didalam Volume Valid	Latitude pas ditengah, Longitude pas ditengah, Altitude pas ditengah	Valid	Berhasil, Pesan: "Absensi berhasil."	YA	
2	Diluar Batas Utara (MaxLat)	Latitude > MaxLatitude, Longitude valid, Altitude valid	Tidak Valid	Gagal, Pesan: "Anda berada diluar area sekolah."	Ya	

No	Komponen Pengujian	Lokasi Uji (Latitude, Longitude, Altitude)	Hasil Diharapkan	Hasil Aktual Sistem	Nilai	
					Sesuai	Tidak
3	Diluar Batas Selatan (MinLat)	Latitude < MinLatitude, Longitude valid, Altitude valid	Tidak Valid	Gagal, Pesan: "Anda berada diluar area sekolah."	Ya	
4	Diluar Batas Timur (MaxLon)	Latitude valid, Longitude > MaxLongitude, Altitude valid	Tidak Valid	Gagal, Pesan: "Anda berada diluar area sekolah."	Ya	
5	Diluar Batas Barat (MinLon)	Lat valid, Lon < MinLon, Alt valid	Tidak Valid	Gagal, Pesan: "Anda berada diluar area sekolah"	Ya	

The results prove that the AABB algorithm successfully validates student locations within the defined 3D volume and consistently rejects attendance from outside the configured boundaries, both in horizontal and vertical dimensions.

C. Device Compatibility Testing

Testing was conducted on 20 Android devices with variations in brand, hardware specifications, and OS versions (Android 9-14).

Table 4. Summary of Device Compatibility Testing Results

Category	Number of Devices	Installation Result	Functional	Performance
Android 14	3	100% successful	100% running	High accuracy
Android 13	5	100% successful	100% running	Good accuracy
Android 12	5	100% successful	100% running	Good accuracy
Android 11	3	100% successful	100% running	Good accuracy
Android 10	2	100% successful	100% running	Fair accuracy
Android 9	2	100% successful	100% running	Fair accuracy

The results show full compatibility across all tested devices, with the application running stably and main features functioning properly.

Discussion

System Advantages

Comprehensive 3D Validation: The AABB algorithm implementation enables validation not only on horizontal perimeter but also on vertical altitude range, preventing location manipulation from upper floors of buildings surrounding the school (Ericson, 2004).

Computational Efficiency: With O(1) complexity, the AABB algorithm is highly efficient for real-time applications compared to methods such as Point-in-Polygon which has O(n) complexity.

Real-time Monitoring: Firebase Realtime Database integration allows teachers to view student attendance status directly without manual refresh (Hasibuan & Triase, 2022)

Intuitive Visual Interface: The use of Mapbox 3D with FillExtrusionLayer provides clear visual representation for validation area configuration (Novriansyah, Simatupang, & Sujjada, 2023).

Structured Architecture: The use of Laravel (MVC) and Flutter frameworks provides a foundation that is easy to manage and has good scalability potential (Otwell, 2021).

Comparison with Previous Research

Compared to the research by Fauzan et al. (2025) which used the Haversine Algorithm with a 2D circular fence of 300-meter radius, this system is more precise because it uses a rectangular shape (AABB) that is more suitable for school areas and adds altitude validation. Research by Sudirman et al. (2025) and Lihoko (2024) was also still limited to 2D Geofencing without altitude validation.

The novelty of this research is the implementation of a 3D virtual volume fence that provides layered security against location manipulation, both horizontally and vertically.

System Limitations

Dependence on GPS Accuracy: The effectiveness of 3D validation depends on the accuracy of mobile device location data, especially altitude which can vary depending on sensor quality (Zandbergen, 2009).

No Mock Location Detection: The system has not yet implemented sophisticated mechanisms to detect GPS spoofing applications.

Internet Connection Dependency: The system requires a stable internet connection for the check in process and real-time synchronization.

CONCLUSION

This research successfully developed a prototype mobile-based student attendance system with 3D Geofencing implementation using the AABB algorithm. Testing results showed a 100% success rate in functional testing and Geofencing accuracy, as well as full compatibility across 20 tested Android devices. The novelty of this research lies in three-dimensional location validation that not only checks horizontal coordinates but also student altitude, providing layered security against location manipulation.

The system proved to improve attendance process efficiency, attendance data accuracy, and significantly prevent location manipulation. Firebase Realtime Database integration enables real-time monitoring, while the Mapbox 3D interface facilitates validation area configuration. This research provides an important contribution to the development of Location-Based Services systems for the education sector.

Recommendations for Future Research:

1. Develop mock location detection mechanisms
2. Implement more complex 3D Geofencing algorithms for non-rectangular areas
3. Conduct load testing for scalability
4. Add offline features for limited internet connection conditions

REFERENCES

Dewi, R., & Maulana, F. (2021). Analisis Sequence Diagram pada Sistem Informasi Pendidikan Berbasis Web. *Jurnal Teknologi dan Komputer*, 10(2), 87–94.

Ericson, C. (2004). *Real-Time Collision Detection.* CRC Press, ISBN: 978-1558607323.

Firmansyah, A., & Rachman, I. (2022). Perancangan Use Case Diagram untuk Sistem Ujian Berbasis Android. *Jurnal Teknologi Informasi Terapan*, 12(1), 44–53.

Gupta, A., & Kumar, V. (2021). Geofencing: A comprehensive survey on concepts, technology and applications. *Journal of Ambient Intelligence and Humanized Computing*.

Hasibuan, M. I., & Triase, T. (2022). Implementasi sistem database NoSQL secara realtime menggunakan Firebase Realtime Database pada aplikasi Ourticle. *SIBATIK JOURNAL: Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, dan Pendidikan*, 2(1):1-24 DOI: 10.54443/sibatik.v2i1.489.

Hidayah, F., & Saputra, A. (2024). Pemanfaatan Android dalam Pengembangan Aplikasi Ujian Online Sekolah Menengah. *Jurnal Ilmiah Informatika Pendidikan*, 12(1), 56–64.

Maulana, D., & Rachmat, A. (2022). Pemanfaatan Flutter dalam Pengembangan Aplikasi Pendidikan Berbasis Mobile. *Jurnal Teknologi Informasi Pendidikan*, 10(3), 211–220.

Novriansyah, M. A., Simatupang, D. S., & Sujjada, A. (2023). Geographic Information System Mapping of Legal Waste Disposal Site Locations in Sukabumi. *G-Tech: Jurnal Teknologi Terapan*, 7(3), 1194–1206 DOI: https://doi.org/10.33379/gtech.v7i3.2869.

Otwell, T. (2021). Laravel: Up & Running: A Framework for Building Modern PHP Apps.

Pressman, R., & Maxim, B. (2023). *Software Engineering: A Practitioner's Approach (9th ed.).* McGraw-Hill Education.

Santoso, H., Suharso, W., & Hariyady, H. (2022). Pembangunan aplikasi mobile hybrid pada M-voting pemilu raya Universitas Muhammadiyah Malang. *IJAI (Indonesian Journal of Applied Informatics)*, 5(1), 12-22.

Setiawan, A., & Nurhayati, L. (2022). Unified Modeling Language (UML) sebagai Alat Bantu Perancangan Sistem Informasi. *Jurnal Sistem Informasi dan Komputer*, 12(2), 101–110.

Sudirman, B., Susatyono, J. D., & Azhari, M. N. (2025). Implementasi Geofencing pada Sistem Presensi Siswa dengan Verifikasi Lokasi Secara Real-Time: Studi Kasus SMK Islamic Center Baiturrahman. *Jurnal Teknik Mesin, Elektro dan Ilmu Komputer (TEKNIK)*, 5(2), 24-35. https://doi.org/10.55606/teknik.v5i2.7131.

Suryani, E., & Putra, H. (2021). Penerapan UML dalam Pengembangan Aplikasi Mobile Berbasis Android. *Jurnal Ilmiah Teknologi dan Sistem Informasi*, 9(2), 87–96.

Tresnani, Lestari, D., & Rinaldi, M. (2012). Implementasi Sistem Absensi Pegawai Menggunakan QR Code Pada Smartphone Berbasis Android. *Jurnal Sarjana Institut Teknologi Bandung Bidang Teknik Elektro dan Informatika*, 1(2), 257–261.

Yuliani, R. (2020). Pengembangan Aplikasi Mobile Learning Berbasis Android untuk Meningkatkan Efektivitas Pembelajaran. *Pengembangan Aplikasi Mobile Learning Berbasis Android untuk Meningkatkan Efektivitas Pembelajaran*, 13(1), 25–33.

Zandbergen, P. A. (2009). Accuracy of iPhone Locations: A Comparison of Assisted GPS, WiFi and Cellular Positioning. *Transactions in GIS*, 13(s1), 5-25.