IRJIEST 11, 2025 XX-XX
Available online at https://ojs.batstate-u.edu.ph
International Research Journal on Innovations in Engineering, Science and Technology

ACTApp: A contact tracing and monitoring application with exposure notification

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ABSTRACT
In response to the global COVID-19 crisis, digital contact tracing emerged as a vital tool for mitigating viral transmission. Recognizing the limitations of manual systems within Batangas State University, the researchers conceptualized ACTApp, a mobile and web-based application designed to automate exposure notifications and health monitoring. The study leverages Global Positioning Satellites (GPS) and Wi-Fi technologies to enhance location tracking, while addressing the challenges of indoor accuracy and data synchronization. Grounded in the principles of responsive design and community-specific implementation, the project reflects a proactive approach to institutional health resilience.

Keywords: contact tracing, GPS, Wi-Fi, Google Maps API, location tracking

Received: August 23, 2025 **Revised:** December 6, 2025 **Accepted:** December 11, 2025 (Article in Press)

1. Introduction
According to the World Health Organization (WHO) [1,2], as of November 23, 2021, there were over 256 million confirmed cases of COVID-19 globally, including approximately 5.1 million reported deaths. The Philippines ranked 27th worldwide in terms of total COVID-19 cases, with 1,149,925 cumulative confirmed cases, 9,595 newly reported cases, and 13,159 total recorded deaths, including 10 new fatalities on that date. The number of cases in the country continues to rise since the first confirmed case on January 21, 2021. Due to record-breaking surges, another round of Enhanced Community Quarantine (ECQ) was implemented in the National Capital Region (NCR) and nearby provinces such as Bulacan, Cavite, Rizal, and Laguna. Although Batangas province was not included in this stricter ECQ, the Department of the Interior and Local Government (DILG) in Batangas was directed to immediately implement the enhanced Prevent-Detect-Isolate-Treat-Reintegrate (PDITR) strategy to limit mobility and reduce delays in case detection, contact tracing, and isolation.

In the study of [3], it was argued that contact tracing apps are not a definitive solution to the COVID-19 crisis. They expressed concerns that such apps could be misused or spread disinformation, potentially offering a false sense of security that might justify premature reopening of economies. Their recommendations aim to minimize the risks associated with technological interventions that appear increasingly inevitable. Despite these concerns, digital technology plays a vital role in collecting large-scale data that can support the ongoing fight against the pandemic [4,5]. In some countries, they see the use of contact tracing as a way to support their fight against COVID-19 [6,7]. These technologies serve as alert systems for users, helping them respond proactively to potential exposure. People have been battling this pandemic for over a year, and with the available technologies, it is essential to leverage digital tools to help contain and prevent the spread of the virus.

The pandemic caught the global population unprepared, leaving governments and institutions scrambling to respond. In the Philippines, the government launched a multi-sectoral response through the Inter-agency Task Force (IATF) on Emerging Infectious Diseases, chaired by the Department of Health (DOH). The National Action Plan (NAP) on COVID-19 was designed to contain the virus and mitigate its socioeconomic impact. As part of this effort, DOH and other agencies developed various applications to accelerate contact tracing [8]. However, despite the proliferation of apps from government agencies, private sector, startups, and tech companies, there remains a lack of a well-crafted, reliable contact tracing application. Many of these apps received negative feedback due to poor performance, slow loading times, and non-functional features. While imperfections are expected during initial development phases, the need for continued research and innovation in this area remains critical.

To contribute to this effort, the researchers proposed the development of a contact tracing application with exposure notification capabilities specifically for the Batangas State University community. Currently, the university uses QR codes for contact tracing, but the process remains manual. Nurses across campuses check submitted Google Forms daily to identify possible exposures, which is inefficient and prone to delays. Accordingly, digital contact tracing apps can help control virus transmission by identifying exposed individuals and encouraging voluntary self-isolation [9]. The researchers believe that effective contact tracing should begin within communities, as each has its own health protocols. A community-specific app can eventually evolve into a nationwide solution. It will also focus on exploring GPS and Wi-Fi as a way to support the contact tracing capabilities of the application. GPS can help provide a wide area of location tracking, which may improve the identification of the location

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where users are currently located in the premises of the campus.

Supporting this claim, Staysafe PH [10] is a government-funded app developed in collaboration with DILG for different Local Government Units (LGUs). Released in May 2021, StaySafe PH assigns unique QR codes to establishments, and users scan them. They get notified if they come in contact with someone who has tested positive. It utilizes geolocation data for contact tracing. Upon installation, users must enable data services, allowing the app to log their location and monitor nearby users. If a user becomes infected, authorities can access their StaySafe data to notify others who may have been exposed. At the same time, other contract tracing apps were also developed to monitor newer variants amidst the COVID-19 Pandemic [11,12]. However, most of these apps lack transparency regarding its detection mechanisms and impose data costs on users. Reviews have criticized its slow performance and poor interface, reinforcing the need for a well-developed contact tracing app that can reliably serve its purpose. Some other concerns also arise from the data collection done by the apps, security of the data collected, and their ethical boundaries in managing the data collected [13-15].

This research project was undertaken to design and implement an integrated mobile and web-based platform capable of automatically detecting possible exposure among university employees. The system was envisioned to support the university's Health Services Office by enabling efficient data management and report generation. To achieve these objectives, the project focused on several key components: 1) the creation of a client application to collect and transmit user data, 2) the development of a server application to receive data and disseminate exposure notifications, 3) the integration of the Google Maps Application Programming Interface (API) for location tracking, 4) the construction of a web application for administrative data management and reporting, 5) the testing and evaluation of the system's overall functionality, and 6) the transfer of the technology to partner communities and local government units.

2. Materials and methods

Figure 1 illustrates the mobile development life cycle, a methodological framework that will guide the researchers in developing the proposed application. The process begins with the identification of the problem statement. Although numerous contact tracing applications already exist in the Philippines, many of these still require continuous improvement and further exploration.

Figure 1. Mobile development life cycle.

The next phase, idea verification, involves extensive research and literature review to gain deeper insights into the proposed application, particularly how it will differ from existing solutions and what significant enhancements it will introduce. This is followed by the design phase, which focuses on the user interface. As the front-end component of any application or software, the user interface plays a critical role in usability. Previous reviews of contact tracing apps have highlighted issues with user-friendliness. In response, the researchers aim to develop an intuitive and accessible interface that caters to users across all age groups, with particular consideration for senior citizens.

Following the design phase is development, which constitutes the back-end programming and system architecture. This is where the core functionalities of the application are built. Application testing is a crucial step in this process, as it ensures the reliability and readiness of the final product. Once the application has been thoroughly tested and confirmed to be free of errors, it will proceed to the deployment phase. This includes publishing the app on platforms such as the Play Store or App Store. The final stage involves marketing and promotion to ensure widespread adoption and effective utilization of the application [16].

In developing the proposed application, the researchers employed several key tools and technologies, including PHP (Hypertext Preprocessor) version 7.4, an online database such as MySQL database, and a REST (Representational State Transfer) API—specifically Google Maps API. To begin with, PHP is a versatile, general-purpose programming language that is widely used in web development due to its flexibility and server-side capabilities [17]. Furthermore, the application will utilize an online database—a data storage system accessible via a local network or the Internet, unlike traditional databases stored locally on individual devices. This setup enables real-time data access and manipulation, allowing queries to be executed remotely and efficiently. In addition, the system will incorporate an API, which functions as an intermediary between different software applications. This facilitates seamless communication and data exchange. Specifically, the REST API follows an architectural style that uses Hypertext Transfer Protocol (HTTP) to transmit data between the server and client applications [18]. This ensures standardized, scalable, and efficient interaction across the system's components.

Figure 2 illustrates the Wi-Fi integration, while Figure 3 presents the GPS functionality embedded within the application. As part of the protocol, any individual entering the university must first complete a health declaration form. For employees, this form is already integrated into the attendance monitoring system. Meanwhile, visitors are required to complete the same form, which will be stored in a separate database. In terms of system functionality, both mobile data and Wi-Fi connectivity will work in tandem to support the application's operations. Once the health declaration form is submitted, the app will continue to function in the background, even if the user disables mobile data or loses internet connection. All collected data will be stored locally and automatically transmitted to the server once the device reconnects to a network.

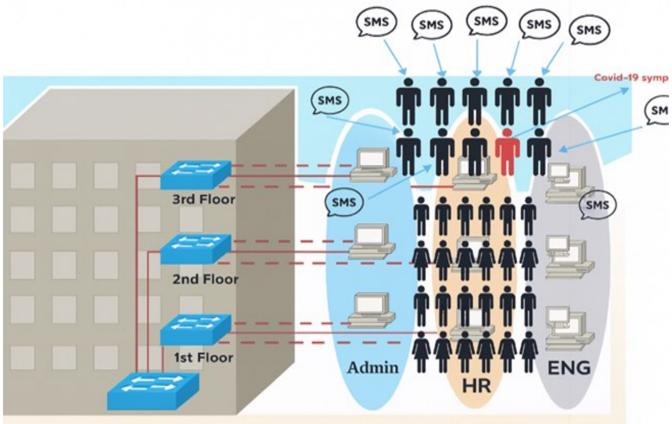

Figure 2. Wi-Fi illustration.

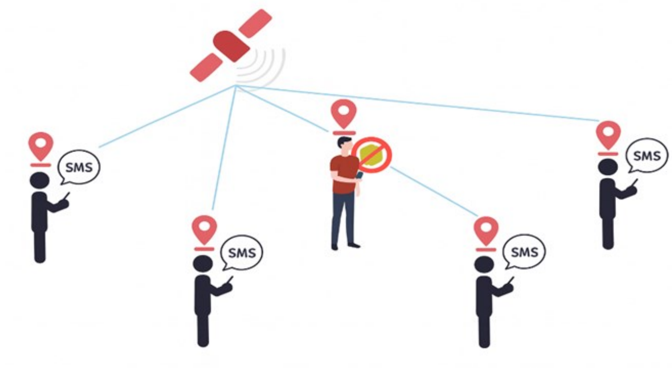

Figure 3. GPS illustration.

Through this mechanism, individuals identified as potentially exposed will be promptly notified and advised to take precautionary measures in accordance with the protocols of the Health Services Office.. The GPS module embedded in the app offers an accuracy of at least 3-5 m radius from the reference point of the user [19]; however, physical obstructions may reduce this precision. In such cases, the app will continue to operate in the background, storing all relevant data.

Moreover, the university and community Wi-Fi infrastructure will supplement GPS tracking when its accuracy is compromised. Wi-Fi routers will identify access points to determine user proximity in the absence of reliable GPS data [20]. The combined accuracy of GPS and Wi-Fi-based location tracking is estimated at 2-5m [21], ensuring reliable and responsive exposure detection.

To evaluate system performance, a series of test cases will be conducted following the release of the completed application and web system. These tests will primarily focus on assessing the functionality and reliability of the system. Test cases are designed to determine whether the website and mobile application are ready for deployment and actual use. Each test case is intended to verify a specific feature or functionality. To quantify performance, the success rate of the website and application will be calculated using the formula: $n/t*100$ = success rate percentage, where: t = total number of test cases, and n = number of successful test cases [22]

In addition to functional testing, the system will undergo location accuracy testing using an external application capable of capturing real-time data via the GPS. This approach will help determine how accurately the application tracks individuals who use the system [23].

3. Results and discussion

This section presents the outcomes of system testing and validation, including GPS accuracy, development constraints, and other concerns identified during implementation. The client application was successfully developed, allowing users to input essential data for contact tracing. These data points are utilized for information gathering, exposure detection, and report generation.

3.1. Test cases for functional testing

The website and mobile application were subjected to a series of predefined test cases to assess their readiness for deployment. These test cases were used to validate specific features and functionalities. The success rate was calculated using the formula mentioned above. The frequency of testing varied depending on the number of users and administrators involved. At present, the website system is managed by four designated administrators.

Based on the results of the test case analysis, the administrators identified several areas of concern regarding the website's functionality. As presented in Table 1, Task 1 and Task 2 were successfully executed. The administrators were able to log into the system using the provided credentials and access the records submitted by employees, enabling them to monitor reported symptoms effectively.

Table 1. Test case for website with Administrator as user

Task No.	Task Description	Expected Results	Results	Remarks
1	The administrator can access the system with the correct username and	The administrator is able to access the system	4/4 = 100%	Passed
2	View list of employees who has completed the health declaration	The administrator is able to determine who has completed the health declaration	4/4 = 100%	Passed
3	Determine which employee has symptoms and identify their location	View symptoms for employee and access Map location where the employee was located	2/4 = 50%	Failed
4	View Map where employee traveled with-in the campus	Administrator can see the different pins on the map location indicating an employee's last location	2/4 = 50%	Failed

However, Task 3 and Task 4 revealed notable challenges. The administrators experienced difficulty in accurately determining the locations of employees due to limitations in the system's location services—particularly the GPS module, which failed to deliver precise, pinpoint coordinates. GPS technology relies on a clear, unobstructed line of sight to satellites for optimal performance; however, physical barriers such as buildings and other structures significantly interfere with signal accuracy.

In certain instances, Wi-Fi-based location assistance was able to supplement the GPS data. Yet, in areas with weak Wi-Fi signals, the accuracy of the mapped locations was further compromised. Consequently, the inconsistencies observed in Task 3 directly affected the outcome of Task 4, as the location pins displayed on the map were not entirely reliable.

3.2. Accuracy of GPS location

To evaluate the application's capability to deliver accurate GPS-based location services, the devices underwent rigorous testing to assess their positioning precision. A dedicated test application was employed to capture real-time location data from each device. The results indicated that the accuracy of GPS-based positioning is contingent upon several critical factors:

3.2.1. Satellite connectivity

The number of GPS satellites a device can connect to is a primary determinant of location accuracy. Greater satellite acquisition correlates with improved precision. However, the tests revealed a marked decline in accuracy when employees were situated indoors—particularly within buildings and office spaces—where structural obstructions hindered the device's ability to maintain a clear line of sight with the requisite satellites.

3.2.2. Receiver quality

The performance of the GPS receivers embedded in the smartphones also influenced the devices' ability to process satellite data efficiently. Although consumer-grade smartphones are not engineered for high-precision geolocation, the receivers in the tested units were deemed adequate for the scope of this study, despite exhibiting minor inherent inaccuracies.

To enhance location tracking, the system also integrates Wi-Fi-based triangulation as a supplementary method [24]. In scenarios where GPS signal acquisition is compromised—such as in enclosed or obstructed environments—the application utilizes nearby Wi-Fi signals to approximate the employee's location. Nonetheless, this method offers only a coarse estimation and lacks the reliability and precision of GPS-based detection.

As illustrated in Figure 4, the GPS technology successfully detected the location of the smartphone device positioned inside a building. However, the test results revealed significant limitations in accuracy. Initially, the GPS positioning exhibited a margin of error of approximately ±22 meters from the target location. This figure falls short of the expected performance range for commercially available smartphone GPS modules, which typically offer an accuracy of around ±4.9 meters.

Figure 4. Location accuracy testing (inside building).

Moreover, the test data indicated a substantial deterioration in GPS accuracy over time. Following the initial reading, the location error expanded dramatically to ±1,510.64 m from the actual position. This decline in precision can be attributed to two primary factors: 1) indoor signal obstruction and 2) satellite drift and positional variability.

The device's placement within an enclosed building environment impeded its ability to maintain a clear line of sight with the requisite number of GPS satellites. This obstruction significantly compromised the integrity of the location data [25]. On the other hand, the continuous movement of GPS satellites contributed to the degradation of signal reliability. As satellite positions shifted, the device's initial signal acquisition became less stable, resulting in increasingly imprecise location calculations [26,27].

As previously discussed, an additional test was conducted in an open environment without structural cover. As illustrated in Figure 5, the application successfully detected the smartphone's location and accurately plotted it on the map. Consistent with earlier test results, the initial GPS reading demonstrated commendable precision, with an accuracy of approximately ±5.314 meters. It also slightly exceeds the standard benchmark of ±4.9 meters typically associated with commercial smartphone GPS module.

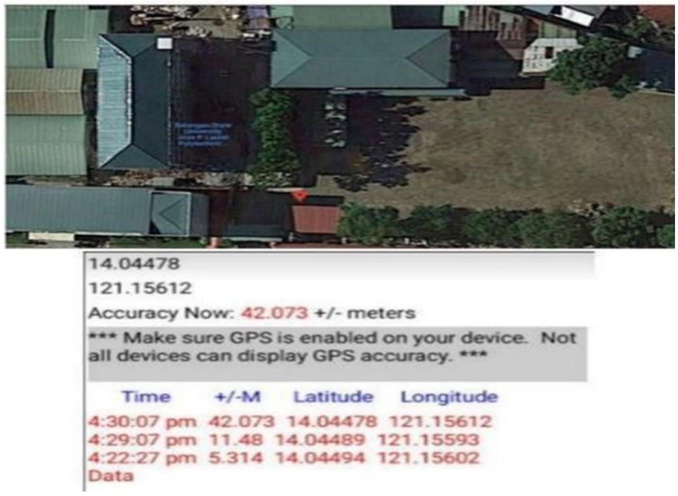

Figure 5. Location accuracy testing (outside without cover).

However, as time progressed, the accuracy of the GPS signal gradually declined. This reduction in precision can be attributed to the continuous orbital movement of GPS satellites, which affects the stability of signal acquisition. Despite the absence of physical obstructions, the dynamic satellite positioning introduced variability in the location data, leading to a measurable decrease in accuracy over time.

4. Conclusions

The results demonstrate that the developed mobile and web applications successfully fulfilled their intended functionalities. The mobile application enabled users to submit health declarations and identify suspected symptomatic cases, while the web-based server component effectively received this data, tracked user locations via the Google Maps API, and generated notifications to alert individuals who had been in contact with reported symptomatic users.

Despite these achievements, the implementation encountered several challenges. Notably, push notifications were unreliable for users without internet connectivity, and GPS-based location tracking exhibited reduced accuracy in indoor environments. To mitigate these limitations, the system integrated Wi-Fi-based location tracking to enhance positional precision. The web application also proved effective in visualizing user locations on a map and generating actionable system reports, including the number of suspected symptomatic cases and submitted health declarations.

Overall, the findings affirm that the developed applications met certain objectives especially on developing the application and storing data collected during the use of the application, providing a functional framework for health declaration monitoring, symptomatic user identification, and contact tracing. Building on these results, future research may focus on improving the robustness and reliability of location tracking and notification systems, particularly in complex indoor settings. It can also be said that the application also has room to improve due to the results achieved in the testing so that location tracking may provide better accuracy even on certain locations. Furthermore, exploring integration with other health monitoring technologies or platforms could expand the system's capabilities and enhance its practical impact in real-world public health contexts.

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