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IoT Technology and STM32 Microcontroller Based Design of Smart Suitcase

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Abstract: Due to the widespread use of smart devices in today's society, conventional suitcases are no longer adequate for the requirements of the average traveller or resident of this era. Many passengers have complained about lost luggage, exhaustion from looking for their bags once they've landed, and a lack of adequate power outlets on the plane. The stm32 and GPS modules form the basis of this design, which is then operated via a mobile phone application to facilitate human-computer interaction and enable intelligent control of the suitcase. The three features of the smart suitcase are as follows: First, Bluetooth secure unlocking can be performed at a short distance via the mobile phone's app, removing the need for the user to memorise a password or carry a physical key. Two, we can tell how far away you are and we won't forget your suit case. Smart In the event that a traveller forgets their bag but their suitcase is nearby, a notification will be sent to their phone. There is no need to spend a long time looking for your suitcase when you are waiting for it next to an airport conveyor belt. Third, the GPS location feature on this bag requires only a negligible amount of data transfer when communicating with the server. To prevent the loss of the suitcase and facilitate the retrieval of the user's belongings if the suitcase were to be stolen, the user's mobile phone terminal need only connect to the server and request the losuitcase the suitcase. For added peace of mind, the smart suitcase is equipped with a safety alarm that will notify the user's loved ones if it does not receive the appropriate instruction within the allotted time.

Keywords: IoT technology, smart suitcase, STM32 microcontrollers, GPS, and bluetooth.

1. Introduction

Due to the difficulty in getting around, few people used to travel. The advent of new machines during the Industrial Revolution [1, 2], however, cut down on our travel times and eliminated some of our options. The suitcase is a traveler's best friend—and worst enemy. Lost luggage and other baggage-related headaches are common complaints. This article presents a design for a smart suitcase that runs on a sophisticated operating system. Connecting with mobile apps, it optimises and improves the features of conventional suitcases by using gravity sensors, a GPS module [3–5], Bluetooth [6], and a WiFi module [7–9]. Travel. Most smart suitcases have features that are meant to address common issues that travellers face, such as losing or misplacing luggage, being overweight, needing to charge electronics while on the go, locking and unlocking, etc.

The "durable and durable" qualities of traditional suitcases used to be more prominent, and the cases all looked the same with no distinguishing features. This shift in functionality is a result of the "smart" application model of the mobile Internet's entry into the suitcase market [10, 11]. As sophisticated computational software and hardware have advanced, those early concepts have become increasingly feasible. Features previously unavailable on the smart suitcase are now possible, including the ability to track the suitcase's weight, location, and opened position, charge wirelessly while on the go, and lock and unlock with the touch of a button.

2. Background

Thanks to modern technology, we no longer have to worry about our luggage at any point during our journey. The smart suitcase revolutionises the travel industry with convenient features like remote lock systems, USB ports [12, 13] for charging electronic devices, and built-in GPS trackers. Developing the software requires knowledge of C programming [14, 15]. The purpose of the design goals for this paper's smart case is to provide a number of useful options.

- Smart lock and unlock: When the user moves further away from the suitcase than a predetermined safety distance, or if the Bluetooth connection is cut off and the suitcase is forced to unlock, the user is notified on their phone.
- Built-in electronic measuring device: The smart bag incorporates an electronic measuring device. After packing, the user need only raise the bag's handle; the accompanying smartphone app will immediately relay the bag's contents and its weight to the user's device.
- Automatically follow: When the user turns on the signal transmitting device they are carrying and move to a certain distance from the suitcase, the signal receiving device on the suitcase detects the transmitting device, performs simultaneous signal processing, and adjusts and generates the device. Adjust the wheel's pointing direction and the suitcase's engine's throttle to propel the bag in unison in the desired direction.
- Infrared obstacle avoidance: The infrared detector and signal receiver built into the suitcase's compartment can quickly detect and process data about potential

frontal collisions. Following a thorough evaluation of the system, the driver can command the motor to advance, halt, or reverse, and the vehicle will then track the user's every move.

- Anti-lost alarm: The security of the suitcase is ensured by a combination of a password lock, electronic lock, and customs lock in the smart suitcase. The suitcase's integrated SIM card and GPS module enable precise, real-time tracking.

Based on a review of the secondary sources, it's clear that the vast majority of the published research and commercial offerings have focused on following or positioning functions. In this article, we will look at how distance detection can be used in design. One of the features of the smart suitcase is a built-in distance sensor [16–18]. Whenever the user's suitcase is in range, a notification is sent to their phone. There is no need to spend a long time looking for your suitcase when you are waiting for it next to an airport conveyor belt. The user will notice a significant enhancement with this change.

3. Proposed System

3.1 Main Function Design

- This product's layout primarily serves three purposes: intelligent unlocking, avoiding the alarm, and losing and retrieving. The main control chip is an Stm32, while the A7GSM/GPRS/GPS module handles GPS positioning and data transmission via cellular networks, and the relay module and electromagnetic lock are responsible for Bluetooth smart unlocking.

- For the second method, smart unlocking, the Bluetooth module will send a command, which will be received by serial port 3 of the stm32. This command will then be used to toggle the PD0 port of the stm32, making it active or inactive. The default configuration for the GPIO port is a low-level [19]. Unlocking the suitcase requires a half-second duration of pulling up on the GPIO port, half-a-second closure of the relay, and half-a-second application of power to the electromagnetic lock.

- Third, an alarm is triggered by an increase in the absolute value of the detected RSSI when the Bluetooth is connected and the APP is some distance from the suitcase. An alarm is triggered in the app when it goes above a predetermined threshold. The PD1 port [20] of the stm32 can be pulled up or down in response to an alarm command sent by the APP, and this is done in the interrupt service program for serial port 3. The GPIO port's default state is "high level." The GPIO port is pulled high whenever the alarm is activated. The alarm is turned off by making the GPIO port go low.

- Send an AT command to the serial port 2 stm32 A7GSM/GPRS/GPS module to locate. The A7 module then feeds the NEMA data it has collected from the AT serial port into the stm32 microcontroller. Make use of the GPRS module and the server to exchange TCP data and send along any pertinent information. Once the server receives data, it processes it and returns it in JSON format. The mobile app connects to the server, pulls the necessary JSON data for positioning, and finds the bag.

3.2 Hardware structure

In this configuration, the STM32 serves as the primary control module, and its serial port is used to implement the various suitcase features [21]. Figure 1 shows the overall design of the smart suitcase Schematic

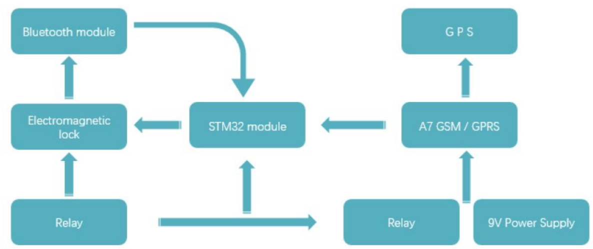

Figure 1. The intelligent suitcase's overall design Schematic

3.3 Information interaction structure

The information exchange between the mobile app and the bag is handled by a server in this setup. Figure 2 is a block diagram of the information interaction structure.

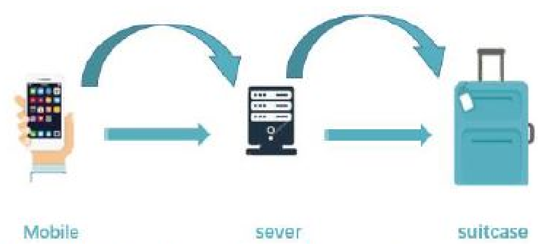

Figure 2. Information interaction block diagram

4. Hardware Design

The following is a list of the essential components that would be used in the proposed system.

4.1 STM32

This layout employs the use of a development board from the STM32F series. The STM32F105 and STM32F107 are the "interconnected" variants of the "basic" and "enhanced" variants, respectively [11, 22, 23]. The STM32f103vet development board is utilised in this design due to its low cost and usefulness in the overall system. The chip is based on an ARM Cortex-M3 core optimised for low-cost, low-power, and high-performance embedded applications. Working at

72MHz, with a plethora of I/O ports, this thing is a powerhouse. Comprises two analog-to-digital converters, three 16-bit timers, one pulse-width modulation timer, two I2C and SPI interfaces, three USART interfaces, one USB interface, and one CAN interface. Figure 3 presents the stm32f103vet6 actual picture.

Figure 3. An illustration of the STM 32

4.1.1 Serial port

There are three serial ports total in this setup. To debug the code on the PC, we use serial port 1. The A7 GSM / GPRS / GPS module receives AT commands and GPS signal inputs via serial port 2. Bluetooth connections are made through serial port 3. The schematic diagram is shown in Figure 4. Table 1 displays a schematic representation of IO and serial port 1.

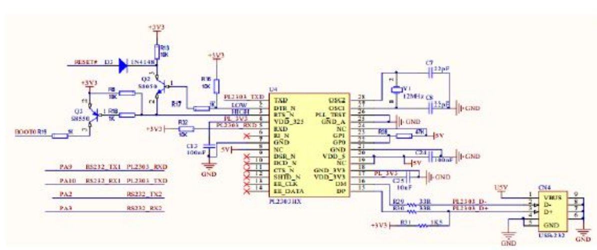

Figure 4. Schematic for the First Series

Table 1. Serial port layout schematic

	Serial port 1	Serial port 2	Serial port 3
TX	PA9	PA2	PB10
RX	PA10	PA3	PB11
Baud rate	19200	115200	9600

The PL2303 has its TXD and RXD pins connected to the RX and TX pins of serial port 1 on the stm32f103VET6, as depicted in the stm32 schematic diagram. The USB 232 interface connects the serial port to the computer, mimicking the appearance and functionality of a standard USB port. Despite being able to send data to the Bluetooth module when connected to the RX and TX pins of stm32 serial port 1, the stm32 is unable to receive data from the module.

4.1.2 GPIO

The unlocking, alarming, and A7 kernel startup procedures all make use of the three IO ports designated as function selection IOs in this layout. Table 2 displays the detailed distribution of GPIO Port Allocation.

Table 2. The specific allocation

GPIO	PD0	PD1	PD4
FUNCTION	UNLOCK	ALARM	A7CORESTART

4.2 A7GSM/GPRS/GPS

Figure 5 shows physical map of A7GSM / GPRS / GPS .

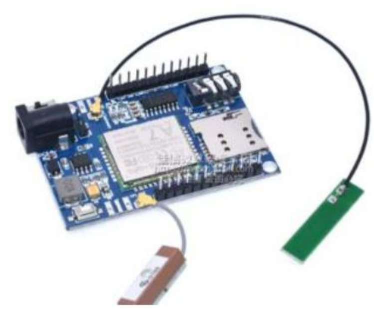

Figure 5. The A7GSM / GPRS / GPS physical map

4.2.1 Dimensions

A7 format, 22.8 x 19.8 x 2.5 mm

- We can work in temperatures anywhere from -30 to +80 degrees Celsius;
- The 850, 900, 1800, and 1900 MHz GSM/GPRS frequency bands;
- One serial port for data download, plus two more serial ports;
- Standard AT and TCP/IP command interface supported via AT command port;

Module dimensions of 62 x 43 x 9 mm; support for China Unicom 2G / 3G / 4G SIM cards; serial communication; default waveform for GPS location information; AT port support (only for A7 devices); GPS location information can be read separately via serial NEMA output (only for A7 devices); 115200 bps is the special rate, with a data bit of 8 and a stop bit of 1.

4.2.2 Kernel boot

The A7 module [24], like a mobile phone's initial startup, requires a large current to boot the operating system. The module will fail to start the kernel normally if the supplied current is inadequate. Therefore, 9V DC is used as the A7 module's power supply voltage in this design. The A7 module is activated by pulling in power via the relay. On-time is measured in milliseconds.

4.2.3 GPS protocol NMEA-0183

The National Marine Electronics Association (NMEA) created the NMEA 0183 standard format for use with marine electronics. According to this protocol, the gathered GPS data is organised. By analysing and retrieving the $GPRMC statement, one can obtain the time and GPS parameters.

4.3 Relay

4.3.1 Specifications

- Module dimensions are 53 x 18 x 18.5 mm.
- Weighs 16 grammes net;
- The VCC port is connected to 5V, the GND port is connected to GND, and the IN port is normally open (signal trigger port).

4.3.2 Function

In this configuration, the relays serve dual purposes: initiating the A7 module's core and opening the suitcase. The normally closed end and public end receive power from the outside world, while the IN port is wired to the stm32's PD4 and PD0 pinouts. The suitcase is unlocked in its initial state, which is indicated by the GPIO port being low, the GPIO port being pulled high, the relay closing, the A7 core being activated, or the electromagnetic lock being closed.

4.4 BLE4.0

4.4.1 Specifications

The Bluetooth module that was developed is a Bluetooth 4.0 module. It is compatible with Android, Apple, and PC, has a connection range of 32.8 feet / 10 metres, a response time of 0.4 seconds, and uses an ultra-low standby power consumption of 90uA-400uA. It's compatible with devices running Android 4.3.3 and higher. It offers enhanced communication compared to Bluetooth 3.0.

4.4.2 Communication protocol

The Bluetooth module's media access control (MAC) address [25, 26] is used as an identifier in this design for added security during Bluetooth data transmission. Users are given a safe place to talk thanks to this protocol.

5. Software Design

The Bluetooth connection in the software allows for short-distance information interaction between the mobile phone and the suitcase, while the GPRS connection transmits the position signal and the server is accessed for GPS information exchange.

5.1 Intranet Mapping

The GPS signal of the suitcase is primarily transmitted in this design via the socket network communication. We talk to one another via the TCP protocol. Different ports allow the server to talk to the suitcase and the mobile phone socket [27]. The problem is that the mobile phone, the server, and the suitcase are not all part of the same local area network. Peanut shells are used to generate the intranet mapping, and the new domain name or IP and port are used to collect and transmit the data.

5.1.1 TCP Protocol:

The Transmission Control Protocol (TCP) is a protocol for the Internet Protocol (IP) transport layer that prioritises established connections and guarantees delivery of data packets. A three-way handshake is used to establish the connection before any data is sent over it. Confirmation, a window, retransmission, and congestion control are all features that help keep data flowing smoothly during transmission. Once the data has been sent, the connection is severed using four pauses. TCP is more reliable than UDP in terms of data transmission. The design relies on TCP communication to guarantee the integrity of the information being transmitted.

5.1.2 Socket Communication:

Sockets are used for communication between processes on a network. The socket mediates between the application layer and the TCP/IP protocol family. Together, an IP address and a port number define a socket.

5.2 Mapped IP and Port

The IP address 192.168.45.41 has been mapped to the domain name 18v87143e7.iok.la via the peanut shell. The mobile phone and server use port 80 for communication, while the suitcase and server use port 8099, which is further subdivided into subports 15116 and 22136 after mapping.

5.3 Sever

This architecture relies on a web server using the Servlet container Tomcat; the specific version of Tomcat used in this design is tomcat6.0; and the development and construction of the server is carried out in the IDE Myeclipse. Initiate the thread in inti and connect to the suitcase's outgoing GPRS signal via the socket. Specifically, 8099 is the port number. In order to keep the server up-to-date, we take the incoming signal, convert it to Json, publish it using doGet, and then refresh the data every second. As a result, the mobile phone can easily acquire the GPS signal, and then use the latitude and longitude it has found to perform the GPS positioning of the suitcase, making it easier to find.

6. Discussion

A high-tech suitcase was developed for the project. I looked at similar products on the market, thought of some new features, and refined the smart suitcase. Operating on Windows 10 with a Tomcat 6.0 web server, as detailed in the project design and implementation overview. MyEclipse 8.5, a programmers' tool, can be used to receive and analyse GPS signals. Peanut shell, a dynamic domain name resolution programme, was also used at the same time. It is possible to set up a host with a permanent domain name after installing peanut shells, registering the shells, and assigning a domain name. Registration of a peanut shell account, addition of a mapping to the intranet penetration, and automatic generation of the extranet IP and port number based on the intranet IP and port number constitute its configuration procedure. Hardware-wise, C is used for development, and keil uvision5 and MCUISP are used to write and debug hardware code, respectively, using the programming languages. This project utilises STM32 chips, which are not found in competing solutions. Product intelligence and industrial automation are two common applications for STM32. It is characterised by being small in size, inexpensive, having robust features, and consuming little energy. The design's central stm32 module allows for information exchange between a mobile device and the suitcase, allowing for precise control of the suitcase and GPS location. Bluetooth allows for short-range data exchange between the mobile device and the bag, while the GPS signal and position signal are transmitted via GPRS and the access server, respectively.

6.1 Security Issues

These numbers are meant to reveal not just the frequency and nature of assaults, but also when they occur, who is typically attacked, and any other relevant details. The greatest risk can be identified using these numbers. Following this research, an evaluation of the structure's susceptibility to assault can be formulated, and the potential for attack can be estimated. The purpose of doing a vulnerability assessment before developing a security strategy is to ensure that the strategy will effectively defend the region. Maintaining a current version of the strategy is crucial. Once a year, you should do a formal assessment of your security plan. If there is a major shift in the organisation or if there is an assault, the security plan should be updated [7]. The proper procedures can be selected with the aid of precedents and norms. However, in most cases, such aims are doomed to failure.

6.2 RFID and Airplane

RFID technology is being adopted by a broad variety of sectors, but commercial aviation appears to be a frontrunner in terms of actual implementation. When compared to the conventional barcode system, RFID technology clearly excels in the area of baggage handling.

It has been shown that efficient luggage handling is a crucial part of providing excellent customer service, and this article demonstrates how RFID technology can help airlines enhance this aspect of their business. Academics and marketers alike would do well to keep tabs on RFID's progress. This is especially crucial in the airline industry, where more precise baggage handling can help companies meet customer expectations despite a challenging business climate.

7. Conclusion

In this article, we propose and outline the design for a smart suitcase that tracks its owner's whereabouts, reminds them of appointments, and sounds an alarm. The project's primary components are its hardware and software components. When it comes to the device's inner workings, STM32 serves as the central control chip, while Bluetooth, wireless communication, etc., are employed, and software is linked via a server. The ability to quickly locate one's bag after stepping off an aeroplane is the most convenient aspect of this smart suitcase. Concurrently, this product greatly simplifies travel for its users and guarantees the security of their bags. You won't have to keep your eyes on your bag the entire time you're on the road, and you'll still be able to figure out where it is so your belongings are safe even if you can't see it. If the user's family has not received the corresponding instruction within the allotted time, the smart suitcase will send a warning reminder that the user is out without them.

References

[1] A. Hassoun, A. Aït-Kaddour, A. M. Abu-Mahfouz, N. B. Rathod, F. Bader, F. J. Barba, A. Biancolillo, J. Cropotova, C. M. Galanakis, A. R. Jambrak *et al.*, "The fourth industrial revolution in the food industry—part i: Industry 4.0 technologies," *Critical Reviews in Food Science and Nutrition*, pp. 1–17, 2022.

[2] M. A. Al-shareeda, M. Anbar, S. Manickam, I. H. Hasbullah, N. Abdullah, M. M. Hamdi, and A. S. Al-Hiti, "Ne-cppa: A new and efficient conditional privacy-preserving authentication scheme for vehicular ad hoc networks (vanets)," *Appl. Math*, vol. 14, no. 6, pp. 1–10, 2020.

[3] M. Zhong, T. Xue, S. X. Ding, and D. Zhou, "On real-time performance evaluation of the inertial sensors in ins/gps systems," in *Fault Diagnosis for Linear Discrete Time-Varying Systems and Its Applications*. Springer, 2023, pp. 389–406.

[4] M. A. Al-Shareeda and S. Manickam, "A systematic literature review on security of vehicular ad-hoc network (vanet) based on veins framework," *IEEE Access*, 2023.

[5] Z.-P. Zhong, X. Zhang, J.-J. Liang, C.-Z. Han, M.-L. Fan, G.-L. Huang, W. Xu, and T. Yuan, "A compact dual-band circularly polarized antenna with wide axial-ratio beamwidth for vehicle gps satellite navigation application," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 9, pp. 8683–8692, 2019.

[6] M. Wang, C. C. Wang, S. Sepasgozar, and S. Zlatanova, "A systematic review of digital technology adoption in off-site construction: Current status and future direction towards industry 4.0," *Buildings*, vol. 10, no. 11, p. 204, 2020.

[7] M. S. Islam, M. K. A. Jannat, M. N. Hossain, W.-S. Kim, S.-W. Lee, and S.-H. Yang, "Stc-nlstmnet: An improved human activity recognition method using convolutional neural network with nlstm from wifi csi," *Sensors*, vol. 23, no. 1, p. 356, 2023.

[8] Z. G. Al-Mekhlafi, M. A. Al-Shareeda, S. Manickam, B. A. Mohammed, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, M. Alsaffar, and T. H. Rassem, "Efficient authentication scheme for 5g-enabled vehicular networks using fog computing," *Sensors*, vol. 23, no. 7, p. 3543, 2023.

[9] Y. Ma, G. Zhou, and S. Wang, "Wifi sensing with chan-

nel state information: A survey," *ACM Computing Surveys (CSUR)*, vol. 52, no. 3, pp. 1–36, 2019.
[10] M. A. Al-Shareeda, S. Manickam, and M. A. Saare, "Ddos attacks detection using machine learning and deep learning techniques: analysis and comparison," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 2, pp. 930–939, 2023.
[11] M. A. Al-Shareeda, S. Manickam, M. A. Saare, and N. C. Arjuman, "Proposed security mechanism for preventing fake router advertisement attack in ipv6 link-local network," *Indones. J. Electr. Eng. Comput. Sci*, vol. 29, pp. 518–526, 2023.
[12] F. Schaumburg, P. A. Kler, C. S. Carrell, C. L. Berli, and C. S. Henry, "Usb powered microfluidic paper-based analytical devices," *Electrophoresis*, vol. 41, no. 7-8, pp. 562–569, 2020.
[13] M. A. Al-Shareeda, S. Manickam, and M. A. Saare, "Intelligent drone-based iot technology for smart agriculture system," in *2022 International Conference on Data Science and Intelligent Computing (ICDSIC)*. IEEE, 2022, pp. 41–45.
[14] D. M. Ritchie, S. C. Johnson, M. Lesk, B. Kernighan *et al.*, "The c programming language," *Bell Sys. Tech. J*, vol. 57, no. 6, pp. 1991–2019, 1978.
[15] B. A. Mohammed, M. A. Al-Shareeda, S. Manickam, Z. G. Al-Mekhlafi, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, and M. Alsaffar, "Fc-pa: Fog computing-based pseudonym authentication scheme in 5g-enabled vehicular networks," *IEEE Access*, vol. 11, pp. 18 571–18 581, 2023.
[16] I. Lima de Paula, H. Rogier, and P. Van Torre, "Conformal integration of efficient conductive-ink-printed antennas in smart suitcases for lpwan-based luggage tracking," *Sensors*, vol. 22, no. 11, p. 4077, 2022.
[17] K. Vijayakumar, P. M. Imran, A. Priya, G. Senthil Kumar, T. S. Angel, and N. Snehalatha, "An iot based smart suitcase embedded with iris recognition and object detection technique," in *AIP Conference Proceedings*, vol. 2516, no. 1. AIP Publishing LLC, 2022, p. 140006.
[18] Z. G. Al-Mekhlafi, M. A. Al-Shareeda, S. Manickam, B. A. Mohammed, A. Alreshidi, M. Alazmi, J. S. Alshudukhi, M. Alsaffar, and A. Alsewari, "Chebyshev polynomial-based fog computing scheme supporting pseudonym revocation for 5g-enabled vehicular networks," *Electronics*, vol. 12, no. 4, p. 872, 2023.
[19] A. Nazarenko, K. Vishnevskiy, D. Meissner, and T. Daim, "Applying digital technologies in technology roadmapping to overcome individual biased assessments," *Technovation*, vol. 110, p. 102364, 2022.
[20] E. J. Lipson, S. M. Bagnasco, J. Moore Jr, S. Jang, M. J. Patel, A. A. Zachary, D. M. Pardoll, J. M. Taube, and C. G. Drake, "Tumor regression and allograft rejection after administration of anti–pd-1," *New England Journal of Medicine*, vol. 374, no. 9, pp. 896–898, 2016.
[21] A. A. El Wahed, P. Patel, M. Maier, C. Pietsch, D. Ruster, S. Bohlken-Fascher, J. Kissenkotter, O. Behrmann, M. Frimpong, M. M. Diagne *et al.*, "Suitcase lab for rapid detection of sars-cov-2 based on recombinase polymerase amplification assay," *Analytical chemistry*, vol. 93, no. 4, pp. 2627–2634, 2021.
[22] B. Quinn and D. Shute, *Windows sockets network programming*. Addison-Wesley Reading, MA, 1996, vol. 1.
[23] M. A. Al-Shareeda and S. Manickam, "Covid-19 vehicle based on an efficient mutual authentication scheme for 5g-enabled vehicular fog computing," *International Journal of Environmental Research and Public Health*, vol. 19, no. 23, p. 15618, 2022.
[24] G. Peng, S. Tsukamoto, K. Okumura, H. Ogawa, S. Ikeda, and F. Niyonsaba, "A pancancer analysis of the oncogenic role of s100 calcium binding protein a7 (s100a7) in human tumors," *Biology*, vol. 11, no. 2, p. 284, 2022.
[25] H.-C. Kim, "A study medium-based safe file management security system on the cloud environment," *Journal of Convergence for Information Technology*, vol. 9, no. 1, pp. 142–150, 2019.
[26] M. A. Al-Shareeda and S. Manickam, "Msr-dos: Modular square root-based scheme to resist denial of service (dos) attacks in 5g-enabled vehicular networks," *IEEE Access*, vol. 10, pp. 120 606–120 615, 2022.
[27] J. E. Sanders, J. L. Garbini, J. B. McLean, P. Hinrichs, T. J. Predmore, J. T. Brzostowski, C. B. Redd, and J. C. Cagle, "A motor-driven adjustable prosthetic socket operated using a mobile phone app: a technical note," *Medical Engineering & Physics*, vol. 68, pp. 94–100, 2019.