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An Approach to Integrate IoT and Mobile Technology for Remote Camera Management

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Abstract

The goal of most control systems is to create external tools that can manage larger, more complex machines. Recently, however, control devices have become more compact, with smaller smart devices being utilized to control larger machines. This shift offers significant advantages in industries, particularly in terms of mobility and simplicity. This study proposes a camera control system designed to use mobile devices through wireless technology, offering enhanced mobility at a lower cost. The system enables a mobile phone to control an intelligent IP camera via Bluetooth and was developed using the Java Application Development Kit (JDK). The design and implementation of this system were informed by research into existing technologies and tools, as well as methods used to bring the research to fruition. several potential areas for future research and development were identified to further improve the system's capabilities.

Keywords: *IoT, internet of things, Mobile device, wireless technology, Bluetooth, I.P. camera,*

Introduction

Control systems in engineering comprise a vast and essential field of study. In recent years, these systems have become integral to daily life, permeating nearly every interaction and activity. Numerous devices and gadgets are designed with foundational principles of control engineering, playing crucial roles in various aspects of our lives. Examples such as home appliances like televisions and advanced systems like space shuttles at the International Space Station illustrate the pervasive influence of control engineering concepts. The evolution of wireless communications and mobile technologies has further expanded the application areas for these concepts. Cameras, traditionally used for monitoring and recording events, have significantly advanced with autonomous capabilities and remote accessibility. Combining these technologies represents a substantial enhancement in modern technology.

Early remote camera systems required direct attachment to a computer or dedicated device to function effectively. Control was typically managed through keyboards or specialized head gestures, such as "head motion" and "head flicking," as described by Dingyun et al. [1]. Scott, Bradley, et al. [2] noted that remote camera systems not only enable user control over camera movements but also over the supporting camera mechanisms. There is a growing demand for multifunctional controls beyond basic camera manipulation, such as Pan/Tilt/Zoom functionalities integrated into contemporary cameras.

A typical remote camera control system includes an IP camera, a stand, a web server application for data transmission, network infrastructure, a storage device or data receiver, and an external control device. This proposed system incorporates additional components like mobile devices (phones) and Bluetooth technology, enhancing flexibility and accessibility.

The entire system was developed using Java, highlighting its robustness and adaptability in integrating IoT and mobile technologies for effective remote camera management.
With the rise of smart devices and advancements in Information Technology (IT), these objectives can now be achieved using compact and efficient mobile technologies [3]. The central aim of this study is to develop a system for remotely controlling and monitoring a camera via a mobile phone using Bluetooth technology, leveraging the Internet of Things (IoT) framework.

A mobile phone was selected as the control device due to its portability and widespread availability, making it ideal for user interaction with the remote camera system. Bluetooth technology was chosen for its low energy consumption, adequate range, and compatibility with mobile devices. Java was selected as the programming language due to its platform independence and strong capabilities in mobile and IoT integration [4].

This study focuses on the ability to control a remote camera via a mobile phone, specifically utilizing Bluetooth and IoT technologies. While the possibility of incorporating multi-device access for dynamic, concurrent control is acknowledged, this falls outside the scope of the current research and is reserved for future work.

Recent advancements in mobile and IoT technologies have opened new avenues for remote system management, particularly in multimedia and real-time applications. This study explores how integrating mobile devices and IoT frameworks can simplify and enhance the control of remote systems, such as cameras, providing users with greater mobility and flexibility.
The ability to remotely manage systems has broad applications across several industries, including healthcare, security, aerospace, robotics, and more, where IoT-driven remote-control systems offer efficiency, safety, and operational scalability.

Literature Review

Mobile phone technologies have become an essential part of daily life for most people, and the industry has increasingly integrated camera functionalities into mobile devices. Information technology industries have leveraged this trend, enabling cameras to be embedded in various gadgets, from laptops to smartphones. It is now "normal to access information, take photographs, record our thoughts, and share these with others through a single device [5]. Although a wide variety of cameras exist, many are still limited by technological constraints such as image resolution, real-time event capture, and autonomous functionality. However, focusing on cameras with autonomous capabilities is essential for achieving the objectives of this research, which aims to integrate IoT and mobile technology for remote camera control.

Cameras with autonomous systems are often referred to as remote cameras or IP cameras. IP cameras, also known as network cameras, utilize Internet Protocol to transmit image data and control signals over an Ethernet link. This aligns with the definition provided by Network Camera Review [6], which confirms that IP cameras function similarly to analog closed-circuit television (CCTV) systems but with enhanced connectivity and network functionality. Many modern IP cameras are equipped with embedded internet video servers or web server systems making them powerful tools for surveillance and remote monitoring.

A typical remote camera management system comprises several components: a remotely controllable camera, a mounting stand, an application to facilitate data transfer, a storage device or data receiver, and a control device. These components work together within an IoT framework, where mobile technology plays a pivotal role in remote access and control. The following section will explore various applications of such systems, emphasizing their role in integrating IoT and mobile technologies for enhanced camera management. In the medical field, the integration of remote camera control systems has significantly enhanced the ability of healthcare professionals to perform procedures more efficiently. As confirmed by [7], cameras are crucial tools for both external and internal imaging in medicine. For instance, dentists use digital imaging technology to enhance diagnostics and treatment by deploying cameras on probes that can be maneuvered inside the mouth, transmitting real-time images to screens for better visibility and patient communication.

In robotics, remote camera systems are integral to navigating dynamic environments and capturing visual data. The field of artificial evolution in robotics, as explored by Morales, et al [8], focuses on developing adaptive behaviors for robots in real-time, allowing them to autonomously adjust to environmental changes. This research has led to advancements in autonomous robot control systems, capable of responding to varying conditions effectively. One key application of remote cameras in robotics involves their attachment to mobile robots, allowing the capture of real-time images from previously inaccessible areas. While these systems face challenges such as bandwidth limitations and connection speed, their use in space exploration missions like the Apollo program demonstrates their potential. Remote cameras attached to robots continue to play a critical role in collecting and transmitting visual data in space and other challenging environments.

Security is one of the most widespread applications of remote camera systems, particularly in the form of Closed-Circuit Television (CCTV). These systems are commonly deployed in parking lots, streets, offices, and various other public and private spaces. Remote cameras used in security require a monitoring system, often referred to as a surveillance system, which retrieves and stores the captured footage for future reference. These systems are frequently utilized by law enforcement and security services. In financial institutions, where fraud and other financial crimes may occur, remote camera systems are essential for monitoring activities and maintaining security. As Turanjanin [9] points out, footage from security cameras is often used as evidence in court to confirm the presence or actions of individuals in specific locations. However, despite their utility, these systems can also be subject to misuse, as noted by Nissenbaum [10], raising concerns over privacy and the potential for criminal exploitation.

The application of remote camera control systems in education is a highly effective and increasingly relevant area. Education, being the foundation of knowledge, faces challenges such as exam malpractice, where students resort to unethical means like cheating to pass exams. Remote camera systems offer a solution to this issue by enabling enhanced surveillance in examination halls. By installing cameras that are controlled remotely by designated personnel, the behavior and conduct of students during exams can be closely monitored. Recordings from these cameras can be reviewed afterward, allowing authorities to make informed decisions based on the footage [11]. This system not only ensures the integrity of the examination process but also deters students from engaging in dishonest practices [13][14][15][16][17].

There are numerous wireless technologies with varying ranges, including radio frequency (RF), infrared light, laser light, visible light, acoustic energy, Bluetooth, and Wi-Fi [11]. The emergence of wireless technologies is seen as a move towards replacing wired connections. Some of these technologies, like 802.11a and Bluetooth, operate without the need for licensing.

In this research, Bluetooth technology is the primary focus. Bluetooth enables communication between diverse devices that implement the technology according to global standards. It is a low-power, short-range wireless technology, ideal for mobile devices, and is integral to the research's objective of controlling remote cameras through mobile phones. Bluetooth follows a specific protocol stack, which ensures compatibility and communication between devices worldwide, making it a suitable choice for IoT and mobile device integration in remote camera management systems.

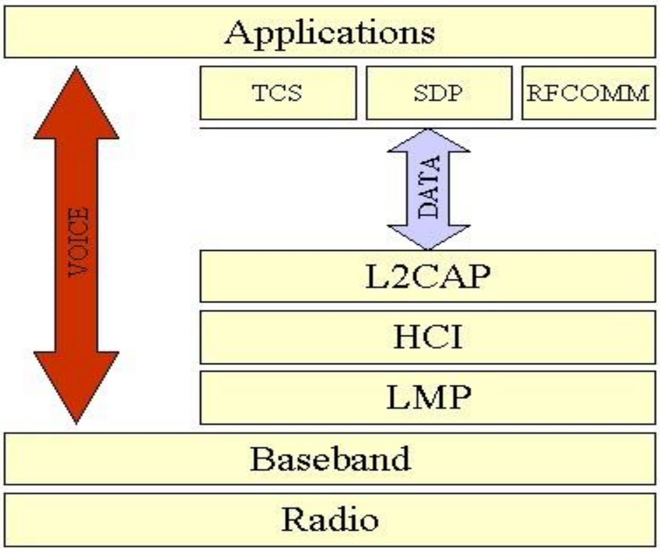

Fig 1 Bluetooth protocol stack

The radio layer is regarded as the physical wireless connection. To avoid interference with other devices that communicate in the industrial, scientific and medical (ISM) band, the modulation is based on fast frequency hopping. Bluetooth divides the 2.4 GHz frequency band into 79 channels 1 MHz apart (from 2.402 to 2.480 GHz), and uses this spread spectrum to hop from one channel to another, up to 1600 times a second. The standard wavelength range is 10 cm to 10 m, and can be extended to 100 m by increasing transmission power. [12]. The baseband layer is said to be in charge of "controlling and sending data packets over the radio link. It provides transmission channels for both data and voice. The baseband layer maintains Synchronous Connection-Oriented (SCO) links for voice and Asynchronous Connectionless (ACL) links for data. SCO packets are never retransmitted but ACL packets are, to ensure data integrity [12]. The Link Manager Protocol (LMP) used to use the links set up by the baseband to establish connections and manage piconets. Responsibilities of the LMP also include authentication and security services, and monitoring of service quality [12].

The Host Controller Interface (HCI) is an interface that "is the dividing line between software and hardware. The L2CAP and layers above it are currently implemented in software, and the LMP and lower layers are in hardware. The HCI is the driver interface for the physical bus that connects these two components. The HCI may not be required. The L2CAP may be accessed directly by the application, or through certain support protocols provided to ease the burden on application programmers [12]. The Logical Link Control and Adaptation Protocol (L2CAP) is used to receive application data and adapts it to the Bluetooth format. Quality of Service (QoS) parameters are exchanged at this layer [12].

The approach to developing this framework builds on the foundational research of existing remote camera control systems. To meet the research's objectives, the ideas from similar systems were adapted to form a comprehensive method. Researching existing similar systems, was crucial as it provided insights into how remote camera management systems are designed and operated. This research enabled the identification of key features that could be beneficial to the new system, allowing for a more informed and efficient development process. Various systems were analyzed, and the most relevant ideas were integrated into the proposed design.

One of the systems that strongly influenced the approach was the Interactive PTZ Camera System. This system was chosen because its architecture closely aligns with the requirements of the proposed IoT and mobile-integrated camera system. The interactive PTZ camera uses wireless control via a Nintendo remote, while the proposed system uses a mobile phone for wireless control. Both systems also feature a server-based intermediate system that facilitates communication between the camera and the control device, making it an ideal model for this research. This systematic approach and integration of existing technologies and new knowledge have resulted in a robust IoT-based remote camera management system, effectively achieving the research's aims.

Research Analysis

After critically analyzing existing systems and available technologies, a structured plan was developed for the implementation of the proposed IoT-based remote camera management system. The insights gained from various researched systems were instrumental in shaping the research's design and functionality.

System Design

The system design was decided and planned out considering a means of communication with a remote camera through a medium (Bluetooth) from the mobile device, the system is designed and illustrated by the fig 2 below.

Fig 2 System Design.

Proper investigation was done with the aid of the internet to research existing hardwares needed for the proposed system. Hardwares, such as camera, network devices, and mobile devices. To make the proposed system as standard as possible the research requires industrial standard devices. Below is list of the selected devices used in the development of the research. Axis M1054 Network Camera: this equipment is an industrial standard I.P. camera that supports voice, PTZ and other functionalities.

Linksys EtherFast Cable/DSL Router model no. BEFSRA1: this equipment is another industrial standard network device that supports TCP/IP, DHCP DSL and other network functionalities.
A computer machine with minimum of 1 gigabyte RAM, 10 gigabyte hard drive, Bluetooth device, and windows XP operating system or any of the like and later. Sony Ericson k800i: this equipment is a mobile phone with the support for java platform, Bluetooth and midp 2.0 and other functionalities. The next section explains the software application used in the implementation of the proposed system. This was a top challenge to decide at the beginning of the implementation of the proposed system due to the following reasons. Application software development kit from camera manufacturer only supports Microsoft development environment and system is required to run on any platform; which means JAVA is at the point in time the best option. The system will have to be able to manage its data autonomously.

Selecting the software development environment was a tough decision as one of the system requirements is to be able to run on a multiple platform. This was a risk and that I had to take.
Adobe Fireworks was used for the interface design and Java was used to implement the actual application design for both the server side (Computer machine) and the client side (Mobile Phone). The server application development side utilize the java2 enterprise edition (J2EE) was used because of its robustness and easy implementation using Netbeans 6.8 version. Also, the client +side application development makes use of the java2 micro edition (J2ME) and it was also done using Netbeans 6.8 version. Netbeans is a java package just like visual studio, it is very robust, very easy and user-friendly application development environment. Netbeans is not restricted to Java only; it can also be used to write scripts in C#, C++, Javascript and so on. Since the proposed system will be making use of some data there must be another application that should handle the data management. Therefore, there is a need for database management software and Microsoft access database application was selected because of its simplicity.
Below are some the interfaces designed prior to the actual implementation of the interfaces in Netbeans. The interfaces were designed as part of the plan as well as to imagine how the interfaces of the application would look like in order to achieve the aim of the research. Below are explained the software interfaces. The server login is designed in a way to get the user's name and password supplied from the operator and then perform login into the main application environment, fig 3

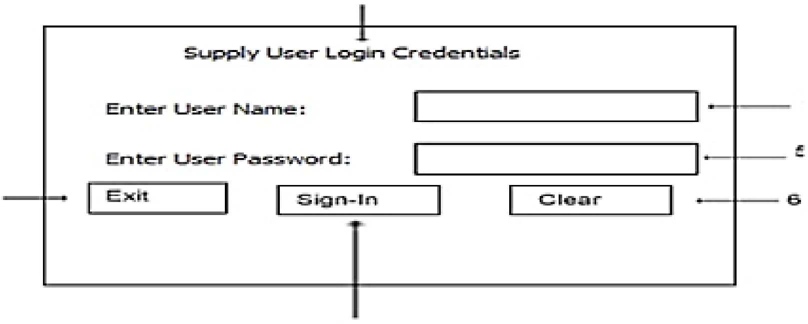

Fig 3 Server Login

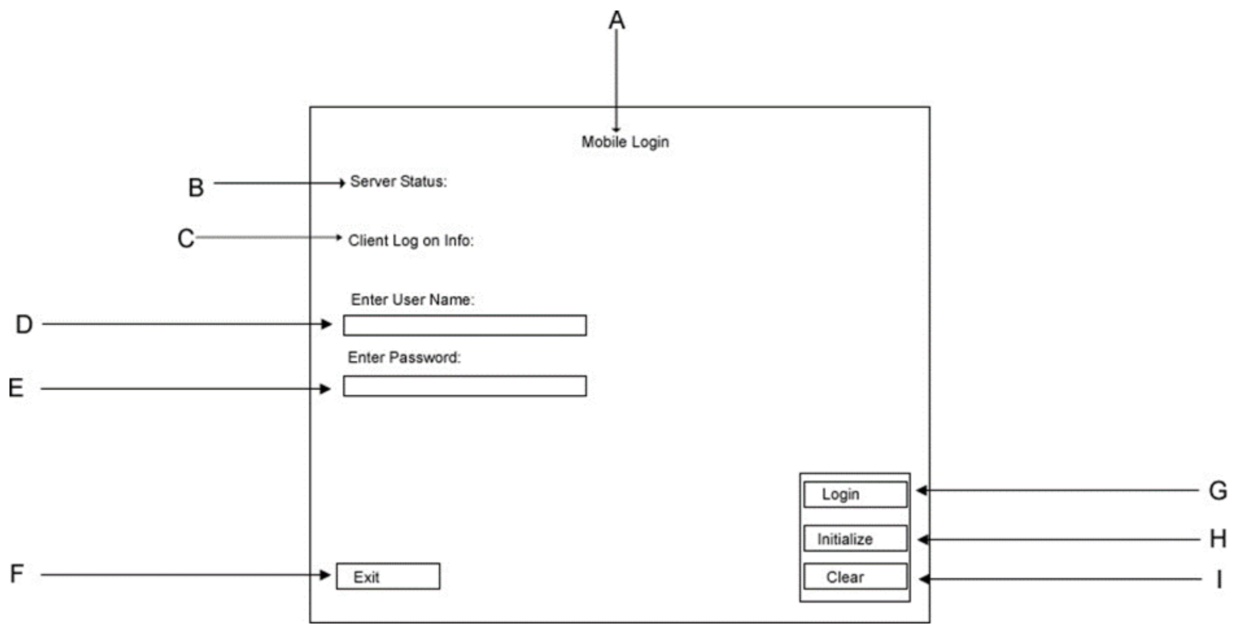

Fig 4: Client Login Design

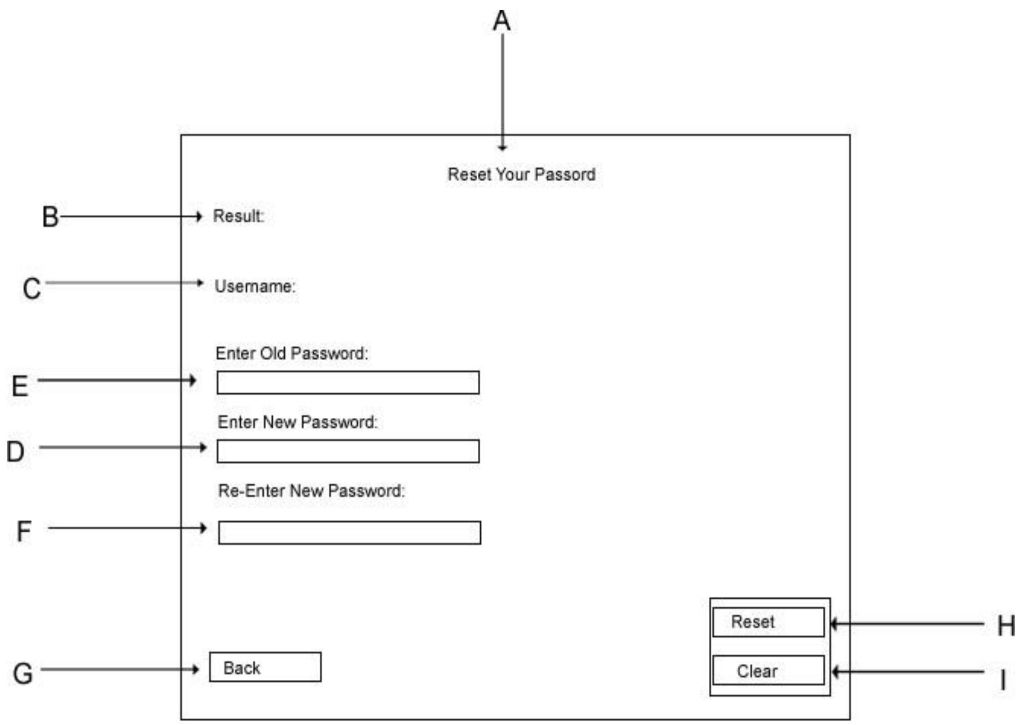

Fig 5: Client Password Reset Form Design

Database Design

When the interface was designed then the next task was to find a means of accommodating the data that will be used for the software. The database design was kept simple so as to avoid complicated data management and to be able to achieve the main aim of the proposed system. Since the database tool selected is relational in nature then simple design was made. See table 1 for the description of the database structure.

Column Name	Data Type	Description
tblUser		For storing user details
Sno	Numeric (integer)	For auto numbering
UID	Text	For storing user names (primary key column)
Pass	Text	For storing associated passwords
Stat	Text	For storing the status of the user
Tblcam		For storing camera credentials
Sno	Numeric (Integer)	For auto numbering
LOC	Text	For storing the camera I.P. address or location (combined primary key column with UID)
UID	Text	For storing the camera user id (combined primary key column with LOC)
Pass	Text	For storing camera password
Stat	Text	For storing the current status of active camera credential that is active
Tbldir		For storing the picture directory string
Sno	Numeric (Integer)	For auto numbering
Dir	Text	For storing the string directory full path string (primary key column)
Tblbt		For storing the Bluetooth number of established connections
Sno	Numeric (Integer)	For auto numbering (primary key column)
Maxno	Number	For storing the current number of Bluetooth connection

Table 1: Database Structure

Software Algorithm

The algorithm is designed to make the application flexible and easily operated, the following points will clarify the software algorithm. When the system (Server) is started it will first check the database and to make sure the database is intact and then performs a user availability check especially the admin account. If the admin account is not found then it will create the admin account and notify the operator as the time of the changes made to the database and then proceeds by displaying the application login form. This form will prompt for the user's name and password to be entered as without this information supplied the operator will not be allowed to proceed from the form. This

login form will validate the user details supplied and then when appropriate data required for the login is tested valid then the program will display the main application main form.
The main application form environment will provide main functions such as the camera pan/tilt/zoom (PTZ) control, camera light control, camera connection, picture capture, mobile devices connection settings, real-time image streaming, mobile device communication, Bluetooth settings, and administration.

Dataflow Diagram

The dataflow diagram illustrates the way the data flows through the system entire proposed system. Fig9 below describes the dataflow of the system.

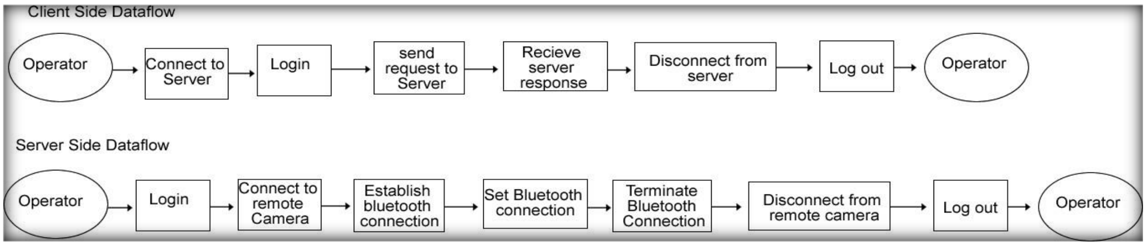

Fig6: dataflow diagram

Flow Chart

The flow chart of the system shows algorithm of the entire operation performed within the proposed system. The following figures illustrate at a glance how the program runs. This flow chart explains the program from when the operator logins into the server side of the application how the application will handle the data from provided in order to display the main application environment with other processes such as setting Bluetooth connection and saving the captured image currently displayed.

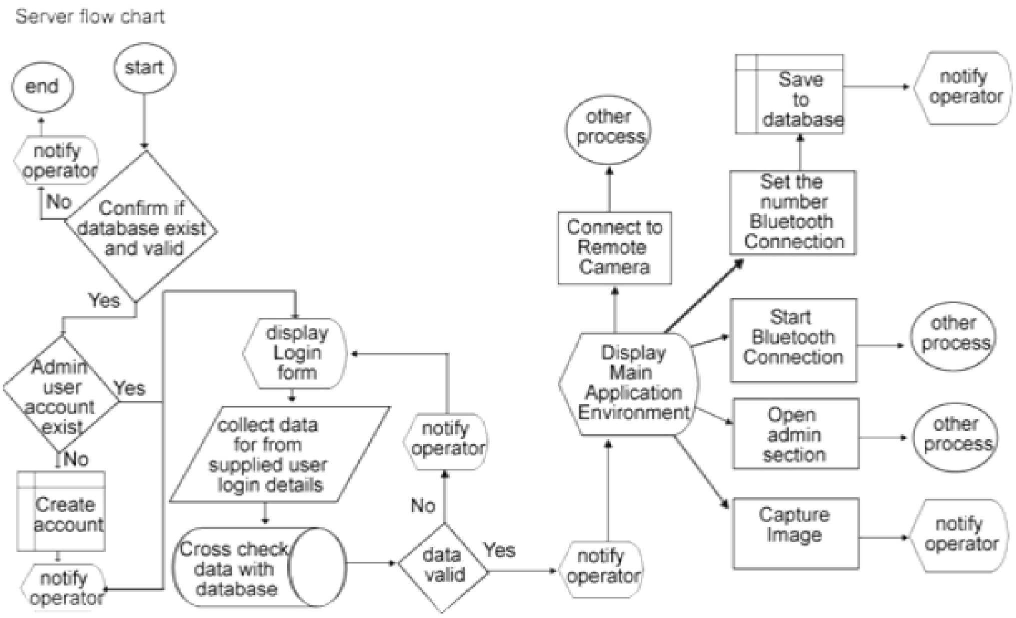

Fig 7: server flow chart A

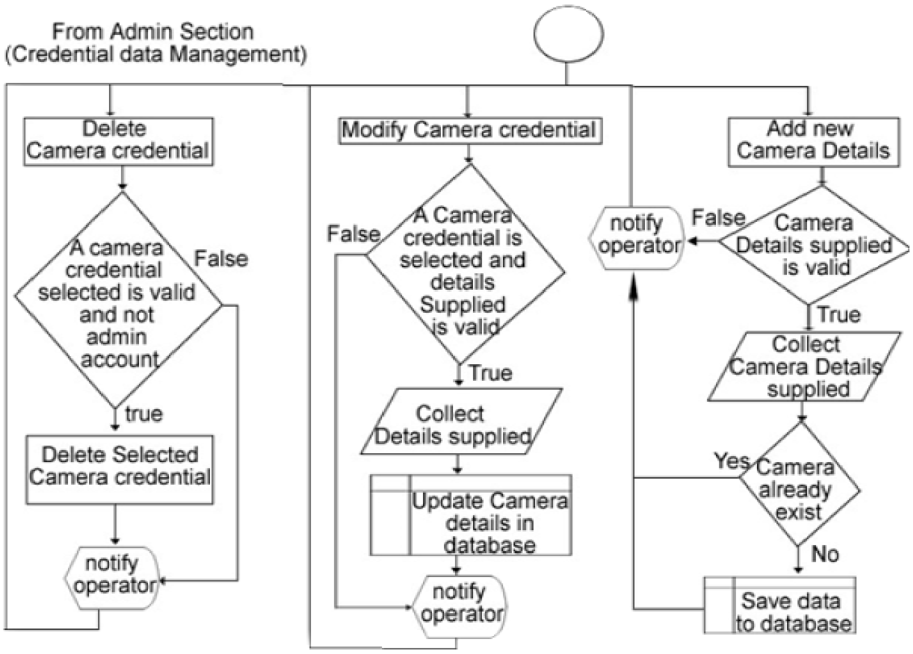

Fig 8: server application

This flow chart gives details at a glance the procedure that occurs when the credential data management section of the admin section is invoked from the server application. The research was executed in stages, the first stage was to research the type of system, then next was to get the requirement of the system, after that a form of survey was conducted to know how and what users of this system would require. Then the development of the system was carried out. After that the system was tested and results were provided. The following statements will explain path of the significant tasks undertaken in the operation of implementing the research.

Survey: this method involved the collecting of information from the users in order to know their view of how this kind of system is to be implemented and what they will prefer in the system.
thereby bringing about how the research can be accomplished to meet the system requirement as well as users, requirement. Analysis of data: the data gathered was analysed and quick and adequate resolution was made, and preparation for the development of the research was immediately underway. Testing: the software involved in the research underwent a lot of tests within stages of development and always ensuring it is free of errors; such as syntactic and semantic before it is finally packaged for implementation.

Challenges: there where series of challenges during the development stages of this paper which brought a necessity to do more research as to find more information about the current challenge. For instance, challenges involved are most technical in nature like the creation of single to multi-point Bluetooth connection was very easier said than done in the execution of the research, other ones which involved transferring images from server-side application to client-side application proved to be another challenging task to do. Another challenge of being able to communicate to and from the server to the client and vice versa.

Conclusion

Extensive research was conducted on existing systems and technologies to understand the requirements and potential challenges. This included studying similar systems, evaluating the technologies to be used, and preparing for any professional or technical issues. A risk management strategy was also developed to handle potential problems during the research. Valuable insights were gained from various Java forums, websites, and professional resources, such as the Sun website. These resources provided essential information on Java technologies, Bluetooth, mobile phone integration, client-server systems, and security. The knowledge acquired was crucial in guiding the research and overcoming technical challenges.

During the development, a significant challenge was the incompatibility of the camera's video codec with the Java Media Framework. The camera's RTSP server provided a video format that could not be handled by the framework. This issue highlighted the need for further research into video streaming protocols and codecs. An alternative approach involving real-time image streaming was adopted, where snapshots were captured at high frequency and combined into a video stream. This solution effectively addressed the video format compatibility issue and enabled real-time display. There are opportunities for further research in areas such as video codec compatibility with Java Media Framework, advanced streaming protocols, and additional features like enhanced video analytics or improved wireless communication. Exploring these areas could provide more robust solutions and enhance the system's capabilities.

In conclusion, the research provided valuable insights and challenges, making the experience both interesting and rewarding. The knowledge gained was significant, and further exploration of identified challenges and new technological advancements could lead to even more innovative solutions in the future.

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