GSM based ATC automation

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ABSTRACT

Air travel is the fastest means of transport. It helps us to reach various places in the world as quickly as possible. This facility is to be controlled properly and also every passenger who travels by air should reach the destination safely. The runway clearance given to the pilots is presently done manually and this human interference is one of the reasons for accidents in the runway. Technological advancements help us achieve highly reliable and relevant systems. To reduce the runway accidents caused by human errors that occur during landing, a GSM-based ATC (Air traffic control) system is proposed. The proposed system automates few processes at the airport by which runway crashes can be avoided, human errors can be reduced and the lives of the people can be saved. The land-request messages and the sensor data from all the points are sent to one common place and decisions are taken from the single base point i.e., the main microcontroller. The microcontroller thus acts as the Air Traffic Control (ATC). It sends the details of the runway clearance automatically to the pilot on receiving a landing request (SMS), only after verifying it to be authorized. If there is an airplane on the runway or in any of the gates, clearance will not be sent. Also, if the request is unauthorized, clearance will not be sent. A centralized GSM authentication is used for sending the clearance message (SMS), to the pilot, which consists of the gate number to land in. Gate numbers will be selected automatically with the help of the information provided by sensors installed at the gates. Sensors that are placed near the runways check whether the runway is busy or not. The flight arriving at each gate is displayed on the LCD.

KEYWORDS

ATC (Air Traffic Control),
GSM,
Message (SMS),
Sensors.

1. Introduction

The number of runway accidents is increasing day by day due to the verbal communication between ATC (Air traffic control) and the pilot. Climatic conditions, runway parameters, air traffic, and other information are checked by the airport personnel and reported to the pilot. After knowing all these parameters, the pilot will decide whether to land on a particular runway or not. Since this process happens manually, the chances of a human error are very high.

Statistics show that many accidents have already occurred due to this manual system. According to the study, around 50% of airplane-related accidents are caused due to the pilot error and one of the reasons is misjudgment by Air Traffic Control [1].

Table 1 depicts few runway accidents caused due to mistakes and misjudgment by the ATC:

Hence some serious measures and new technology have to be developed to avoid these mistakes and misjudgments. To establish a long-distance communication, GSM based system is developed. This enables the messages to be sent and received from various distances without any glitches. GSM networks operate in several different carrier frequency ranges. Using the text message feature of GSM i.e., SMS allows users to send messages up to 160 characters [7]. And thus, GSM standard forms the core technology of the proposed system.

The sensors placed at the runway and the gates check their emptiness and the data is sent to the

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Table 1
Accidents due to mistakes by ATC.

Sl No.	Flight details	Accident details
1	Air Canada Flight 759 – July 7, 2017 [2]	Mistakenly lined up taxiway to land on giving clearance for a runway. The incident occurred on final approach to the airport.
2	Delta Connection Flight 5191 - August 27, 2006 [3]	Runway overrun due to runway confusion by ATC. The runway was too short for safe take-off/ landing.
3	Aer Lingus Flight - June 9, 2005 [4]	Clearance given to 2 airplanes for runways which intersected with each other. The airplanes missed colliding by 70ft distance.
4	Singapore Airlines Flight 006 - October 31, 2000 [5]	Clearance given for a closed runway. The aircraft crashed into construction equipment causing the death of 83 people.
5	USAir Flight 1493 - February 1, 1991 [6]	Runway collision due to ATC error. The airplane collided with a turboprop causes death of 23 people

controller. The communications in the airport between the sensors and the controller are wired whereas the communication between the controller and the pilot is wireless, i.e., through GSM.

The main aim of the proposed system is to ensure that the manual systems do not cause major severities. Also, automation is a very important factor in the system. Another key factor in the proposed system is design optimization. To achieve this, the controller boards are designed from scratch to meet the requirements of the system and ensure maximum automation and optimization. Authorization of the landing requests is done to ensure that there is no security breach as airplanes and airports are prone to hijacking.

Thus the proposed system aims to provide a safe, secure and automated air traffic control and runway clearance, therefore ensuring that the mistakes and misjudgments are avoided and the safety of the people traveling by airplanes is guaranteed.

2. System Design and Process Flow

2.1 Hardware requirements

ARM Cortex M3 (LPC1768)

Arm Cortex M3 is a 32-bit microprocessor that has a 32-bit data path, 32-bit register bank and also 32-bit memory interfaces. The main advantages are low power consumption and low interrupt latency. LPC1768 comes under the family of ARM CORTEX M3. It has Harvard architecture which means it has separate instruction and data bus. This increases system performance. The main features of LPC1768 are:

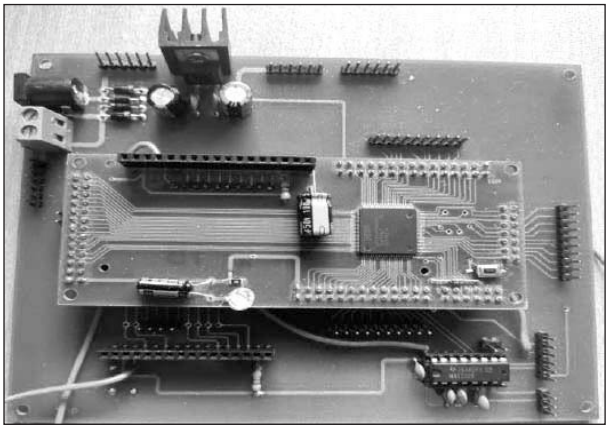

Fig. 1. ARM cortex M3.

The supply voltage ranges from +2.4V to +3.6V in which we use 3.3V. The temperature range is of -40 °C to 85 °C. It supports external clock up to 100MHz and 4MHz internal clock. We don't use the external clock. It has 512 Kb of flash memory and 64 Kb of data memory. It has an Ethernet MAC. It also has a USB Device/ Host/ OTG controller along with an 8-channel DMA controller. It consists of 6-output general-purpose PWM, 4 UARTs and 100 pin package. It has up to 70 general-purpose I/O pins. It has 3 SSP/ SPI, 3 I2C, I2S. It also has an 8-channel 12-bit ADC and 10-bit DAC; it also has motor control. It also consists of 4 general-purpose timers. It has 5 Ports and an on-chip PLL.

Serial Communication

Serial communication is often used to transfer information between data processing equipment and peripherals. Devices like a computer and mobile phones run on serial communication. RS-232, RS-485, I2C are the few interfaces used for data communication. Data is transmitted in the form of binary in serial communication. The transmission modes in serial communication are simplex, half-duplex, and full-duplex.

- Simplex method: It is one-way communication. Both the sender and receiver cannot be active at the same time. If the sender sends the data, the receiver can only accept it.
- Half-duplex: both client and server are active, but not at the same time.
- Full duplex: both sender and receiver can transmit and receive the data at the same time. Cell phones that we use are the best example of a full-duplex.

GSM module

GSM stands for global system for mobile communication. It is used for mobile communication in the world. It is developed using the TDMA technique for communication purposes. GSM is a digital cellular technology used for transmitting mobile voice and data services operating at the frequency bands of 850MHz, 900MHz, 1800MHz and 1900MHz.

GSM Modem: It can either be a mobile phone or a modem device that can be used to make a computer or any other processor communicate over a network. A SIM card is to be operated over a network range subscribed by the network operator. It has to be connected to a computer via serial, USB or Bluetooth connection. A GSM modem should contain an appropriate cable and software driver to connect to a serial port or USB port on the computer. The modem has an ample range of applications in transaction terminals, supply chain management, security applications, weather stations and GPRS mode remote data logging. GSM is an adaptable Quad-band cell phone, that works on a frequency of 850/900/1800/1900MHz. It can be used to access the Internet and also for oral communication. The AMR926EJ-S processor controls the module, which in turn controls phone communication, data communication using an integrated TCP/IP stack, and a UART and a TTL serial interface.

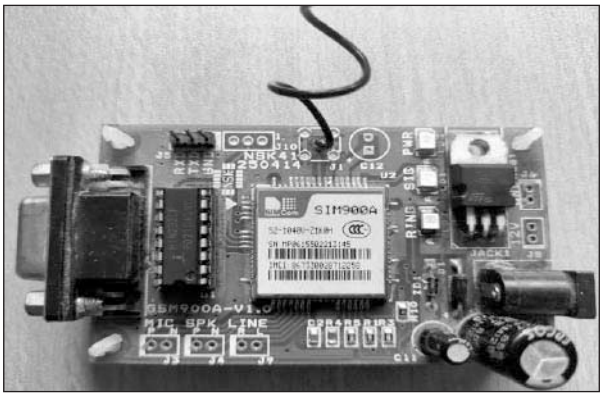

Fig. 2. GSM module.

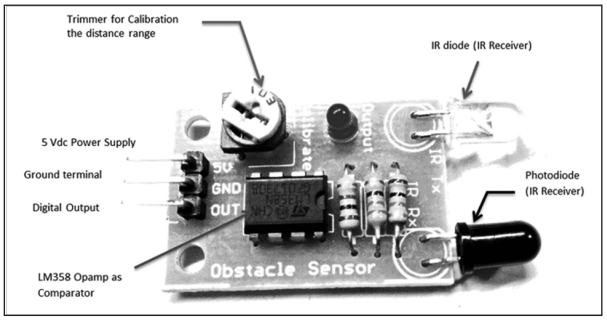

Fig. 3. IR Sensor.

The communication between the controller and the GSM module is carried out through serial communication via MAX232.

IR sensor

An IR sensor emits light to detect any objects in the surroundings. It has an emitter which is an IR LED and the detector that is IR photodiode which is sensitive to IR light of the same wavelength as that is emitted by IR LED. When the IR light falls on the photodiode, the resistance and the output voltage changes in proportion to the magnitude of the light received by IR.

An IR sensor-module consists of 2 parts that are an emitter and a receiver. An emitter is an IR LED and the receiver is an IR photodiode. IR photodiode is responsive to IR light emitted by an IR LED. Resistance and output voltage of the photodiode changes in proportion to the light received by the IR. If the IR LED is placed infront of a photodiode with no obstacle in between it is called direct incidence. If the object is placed in front of the sensors and sensors are placed side by side the light from the LED hits the object and reflects to the photodiode. It consists of:

- IR LED: To emit infrared light.
- Photodiode: To receive IR light.

- Operational amplifier: A voltage comparator
- Potentiometer: To adjust the sensor output according to requirements.

Features:

- 5V DC operating range
- Current: 20mA
- Range: up to 20cm
- I/O Pins: 5V and 3.3V

LCD display

LCD is a combination of two states of matter that is solid and liquid. LCD is composed of some layers which comprise two polarized panel filters and electrodes. We use LCD for displaying on electronic devices such as mini computers. Light setup from the lens on an LCD layer. LCD is further made up of an active matrix display grid/passive display grid. Usually electronic devices build upon LCD technology because of the display. Liquid consumes less power than an LED/cathode ray tube. LCD screen functions on the principle of blocking light sooner than emitting light. It needs backlight while it is not able to emit light on its own. We repeatedly utilize devices that are built up of an LCD. It can recover by cathode ray tube. Cathode ray tube carries more high power than LCD. Cathode ray tube is heavier and bigger.

Unlike CRTs, LCDs allow displays to be much thinner. Rather than emitting light, they use backlight to produce images in color or monochrome. An LCD contains backlight which provides lights to the pixels. It has red, blue and green sub pixel which can be turned on or off using pixel. The display appears black when all the pixels and sub pixels gets off and it appears white when all the sub pixels are turned on. The backlight in the liquid crystal display polarizes the light by sending only half of the light through the layer. By applying voltages, the solid and liquid parts in the display can be twisted. This helps in activating and deactivating the lights of the display.

Fig. 4. 16x2 LCD display.

2.2 Software requirements

Keil µVision 4

µVision is a window-based software development platform. Robust and modern editor are combined by this, that contains a project manager and make the facility tool. The tools needed to develop embedded applications like a C/C++ compiler; macro assembler, linker/locator, and a HEX file generator are integrated by this. In order to accelerate the development process of embedded applications, µVision is used. The µVision IDE and Debugger is the central part of the Keil development tool-chain and has various features which help the programmer in developing the embedded applications successfully and quickly. µVision offers two modes. Build Mode which is used for creating applications and a Debug Mode which is used for debugging applications.

Eagle

EAGLE is an acceptable electronic design automation (EDA) operation with representational acquirement, printed circuit board layout, auto-router, and computer-aided manufacturing features. EAGLE acronym is Easily Applicable Graphical Layout Editor.

Features

It composed an operation editor, for constructing circuit diagrams. Operations are save in files (with .SCH extension), components are regulate in equipment libraries (with .LBR extension). Components can be located on many layers and associated in sync over ports.

PCB layout editor saves board directory with the (extension .BRD). It grants back-interpretation to the representational and auto-routing to associate detect positioned on the connections characterize in the representation. It liberates the Gerber and Postscript layout directory with Excellon and Sieb & Meyer drill files. Standard file pattern by PCB fabrication, EAGLE typical user base of small design firms. Many PCB fabricators and assembly boutique also acquire EAGLE board files (with extension .BRD) straight to export optimized assembly files. A graphical user interface and menu scheme for editing, project management, customize the interface, design parameters. It can be controlled by mouse, keyboard by introducing specific commands at an embedded command line. Multiple repeating commands can be mixed

into script files (with file extension .SCR). To explore draft files utilization of EAGLE-exact oops language is done (with extension .ULP).

Hyper terminal

It comes with Microsoft Windows. It is used to send AT commands to a mobile phone or GSM/ GPRS modem. It is a very useful tool for testing GSM/GPRS modem.

The process for sending AT commands to GSM modem from HyperTerminal is as follows:

1. Insert a SIM card into the modem and plug it on with the adapter
2. Connect the modem to the PC using USB to Serial converter
3. Run HyperTerminal and choose connection description
4. Enter the phone number, area pin code and also choose valid COM number and baud-rate
5. A plain window appears where the AT commands are typed and the GSM modem is tested

2.3 PCB designing

Printed Circuit Board (PCB) is the most required element in electronic circuits and equipment. Method of building an electronic circuit with breadboards and zero boards is considered to be less efficient where the designing of the circuit may be prone to few damages and it may be complex in placing the circuit components. PCBs are made up of insulating materials such as fibers and glass. Instead of wires, copper tracks are used for designing the circuits on boards for better conduction of electricity between the electronic components.

2.4 Designing process of a PCB

PCBs can be designed in various ways. For processes like drilling, punching, plating and other final fabrication processes, a variety of machines are used in fabrication manufacturing industries. There are manual operation and automating machines available in the market. Based on one's requirement, they can choose the required type of machine.

Step 1: Design the PCB circuit with a Software

Step 2: Film generation

Step 3: Select Raw Material

Step 4: Preparing Drill Holes

Step 5: Apply Image

Step 6: Stripping and Etching

Step 7: Testing

3. Implementation and Working

Our system is built for a single runway and 2 gates airport and one-time capacity is three airplanes. Sensors are installed at the runway and also at the two gates to check any intrusion. The distance of intrusion detection is adjusted using the potentiometer of the IR sensor. The GSM initialization time is about 30 seconds and hence there is an initial delay of 30 seconds. So once the GSM is initialized, the messages are received by the modem. The system is built only to approve a valid message format from pre-saved numbers only. Invalid message format or invalid phone number related requests are discarded. This forms the authorization part of the proposed system. On receiving an authorized request, the controller gets the sensor data and allots the gate number to the received request. When all gates and runway is free, the message is sent to land in gate 1. When gate 2 and runway are free, the message is sent to land in gate 2. When only the runway is free, the message is sent to wait on the runway. And when everything is busy, landing permission is not given. Using this concept, a real-life implementation can be done and also the capacity can be increased as per requirement. The communication happens in real-time and is very secure. The security breach is minimal as the message is considered authorized only when both the phone number and the message format match the pre-defined ones. Even if one of those two does not match, the land-request is considered to be invalid and the request is discarded. Thus the proposed system

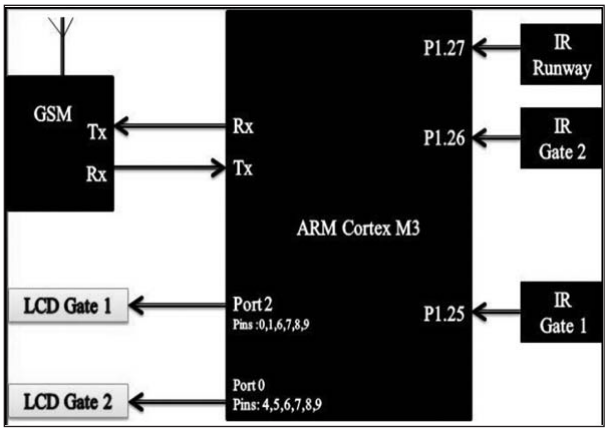

Fig. 5. Block diagram.

aims to give secure automation of the ATC. The microcontroller here acts as the ATC and a base point for all communications.

Experimental Result

The experimental result of the proposed system is obtained based on the sensor output.

1. When gate 1, gate 2 and runway were free, on receiving valid land request the flight was directed to land in gate 1.
2. When gate 2 and runway were free, on receiving valid land request the flight was directed to land in gate 2.
3. When only the runway was free, on receiving valid land request the flight was directed to land and to wait on runway
4. When gate 1, gate 2 and runway were busy, on receiving valid land request the message was sent indicating that the runway was busy.

The status messages of the flight landing at a particular gate are displayed at the gate LCD. Also the statuses like "GSM Initializing" and "Gate No:" are displayed at each gate LCD.

4. Conclusion

This system is designed to avoid runway accidents due to miscommunication and misjudgment by the Air Traffic Control. The GSM technology is chosen for long-distance communication between the Air Traffic Control and the pilot so that the pilot can send a landing request and get a reply from the Air Traffic Control from a far distance. This system continuously monitors the sensor data to ensure that the proper gate number is chosen for every land request. It also provides security features by ensuring only authorized pilots can send a land request and the request must also be in the pre-defined format. This system adds automation to the present manual systems thus making them more efficient and fast. The design of the system is optimized so that it fits the required application perfectly and works efficiently. The design optimization also ensures that there is minimum usage of space by the system. Thus the system is fast, efficient, cost-effective and easy to implement. For future enhancement, the GSM system can be replaced with a radar system and further automation can be brought in various manual systems of the airport.

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