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Industrial Robot Control using GSM network

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Abstract

Controlling devices was one of the important fields, led by robots to do the dangerous, precise and even boring work, the embedded systems study had the main role and contribution in making such control convenient, as it acquire measures, process readings and control actuator. The suggested solution was to control using three modes as well as approaching the problem without using PC as processing and conditioning unit, also to overcome the limitation of AVR atmega32 peripherals that can control only two servo motors, this limit has been overcome by the SPI network of microcontrollers. Results were good as it is functional but with some findings like rounds up some values led to loose of fraction in the moment of sending degree to the slave micro, and there were proposed solution which was to send the value in two cycles, also putting the three modes in one program were not possible because of the blocking statement in the GSM mode.

Keywords: TAVR; SPI; actuator; conditioning; robot; GSM

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1. Introduction

Acquiring the data for analysis and decision making was very important part of life, earlier acquiring these data was done through wires media, this media had a pros which is controlled by controlling the quality of the media and the power of transmitter, but one of the clear limitations that wired communication requires cables and that has a significant difficulties in the longer destination. Wireless communication prosperity helped in linking longer destination for multiple purposes, even countries were able to access their remote sites using wireless communication and sometimes hybrid communication. Embedded systems were a great addition to this domain, cost and size wise. In this paper a review is done to show the progress in the GSM based control specially using SMS.

Microprocessor based embedded systems is different from microcontroller based ones, as the first has greater capabilities on image processing and audio advanced applications but it needs peripherals (that is why it usually comes as development board), programming memory and RAM as well, it has also variety of Real Time operating systems and sometimes it even provides full TCP/IP network stack, USB, HDMI etc. moreover it could have a device driver for any externally connected devices. While the second is for the simpler applications, having embedded programming memory and RAM, peripherals as well and which doesn't need high end processing.

The suggested solution were to achieve automation, special type of actuators could be used to produce the required motion. Motors in general could be used as actuators to control artificial joints, robots. Many types of motors are there DC, Stepper, Servo motors… etc.

1.1 Control systems

Servo is closed loop system which accepts input, process that input and adjusts the rotor, then measures the actual output through sensor a comparator to measure and generate the difference/error and feed it to the controller again to adjust the motor to the right direction accordingly.

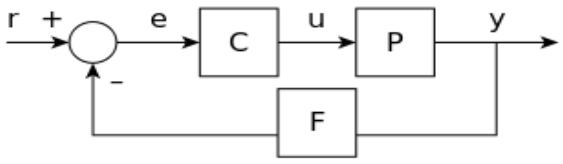

Fig.1 Closed loop system

1.2 Pulse Width Modulation (PWM)

What influence which motor is better to be used in which situation is the type of movement and nature of load. Servos are usually used to achieve movement of motor to specific angles, which leads us to talk about the nature of invoked supply to control the movement is the Pulse Width Modulation (PWM).

PWM is considered a quite well replacement to the use of DC voltage, it is concerned about the duration of pulse and the duty cycle, duty cycle could be defined as the duration of (high duration) per cycle. In the DC motor it is always made use the whole duration of the PWM which will provide a percentage of the total supplied voltage and with the use of capacitor, the equivalent to DC voltage could be generated. The below are the equations for the PWM.

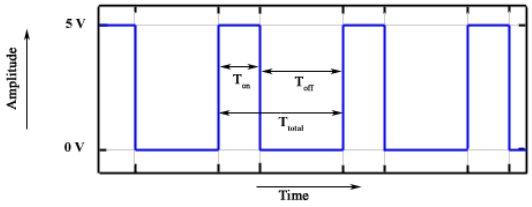

Fig.2 Diagram shows duty cycle

The total pulse duration is expressed by Ttotal while Ton and Toffare the High and Low period respectively:

$$Ttotal = Ton + Toff \quad (1)$$

The Duty Cycle can be calculated by dividing the duration of the high period by the duration of the whole cycle, the result is percentage:

$$D = \frac{Ton}{(Ton + Toff)} = \frac{Ton}{Ttotal} \quad (2)$$

So to calculate the exact voltage the duty cycle is multiplied by the voltage:

$$Vout = D \times Vin \quad (3)$$

$$Vout = \frac{Ton}{Ttotal} \times Vin \quad (4)$$

GSM network is the last component of the project is the wireless media, Global System for Mobile communications GSM, which will be used to send the control commands in one of the operation modes. First of all I will explain the architecture of GSM network which is composed of BSS and NSS which Base Station Subsystem and Network Switching Subsystem respectively, it works as Circuit Switching (voice) as well as Packet Switching (data).

SMS is one of the provided services by GSM network and is widely used by subscribers in all over the world, thus it can be effectively used in control projects. In the Mobile Set side there was a very effective command line tool called AT (short for ATtention), it is also called Hayes Command Set which is developed in 1981 for Hayes Smart modem, they are flexible text commands and could be used to perform all mobile phone operations, SMS set of commands will be used as a main drive for the robot.

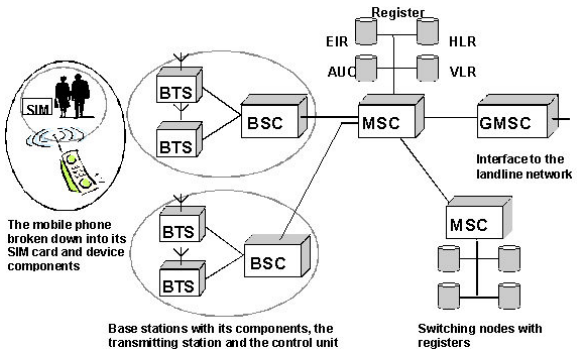

Fig.3GSM network basic architecture

2. Materials and Methods

In the industries and even outside, like in the construction works, there is a lot of work which could be automated and controlled remotely. The problem is addressed by many researches but in different applications.

The first paper is microcontroller based embedded system, it is designed to measure and control humidity using SMS, and it was done using LPC2148 ARM microcontroller, it works by measuring humidity using the humidity sensor which is connected to the controller using the ADC (Analogue to Digital Converter), having bulb indicator if exceeding threshold in addition to SMS alerts. It is flexible system and has track record as it sends the data frequently to the PC which load the data to a database and provide interface to the database using Visual Basic [1].

While the second paper was around home appliance control, it has been abbreviated as HACS and the aim of this research was to develop a new technique of home appliance control and monitor home thru SMS, and the system was divided into two subsystems, the appliance control system was to remotely control home appliances, the second was to alert of any security breach, the first subsystem was configured to advice the user via SMS to change the condition of the home appliance according to the user needs and requirements, The security subsystem was mainly for intrusion detection. The obvioustraits of this system are the dependency on a PC to process and generate SMS fordecisions [2].

The third paper is in the irrigation of the field and very good example of the embedded systems in the agricultural domain, it is used to sense the condition of the farm to evaluate whether it needs to be irrigated or not, and also the availability of the water in the field, controlled by the SMS to switch on the water or switch it off. AT89V51 microcontroller is used along with motor driver, SIM300S GSM modem and moisture sensor, this system detect the status of the field using and sends alerts accordingly to the user, then the user can send a command SMS to switch on or off the motor. With This research added a great value to agriculture field as for some countries those who their economy depends the agriculture, so moving around the field will cost fuel and time as well, moreover such system will help scheduling irrigating [3].

In the fourth research the SMS control embedded systems is used conveniently on E-notice Board, it was simple and nice project on controlling the displayed message on the board which instead of reprogramming the microcontroller every time the message needs to be changed. P89V51RD2 is Philips microcontroller used along with 16x2 LCD, MAX232, and SIM300 GSM modem [4].

3. Results

The servo motors usually make use of PWM in a different way, instead of working in the whole pulse duration even it could be seen like a DC current, it is used in specific duration of the pulse e.g. 1ms to 2ms for some servos. So 1ms is the minimum 0 degrees angle rotation, while the 2ms is the maximum 180 degrees angle rotation, naturally 90 degrees could be achieved by supplying with 1.5ms. PWM could be implemented in a three ways:

- Non-inverted PWM(Fast PWM)
- Inverted PWM(Fast PWM)
- Phase correct PWM

Non-inverted refers to the duty cycle, so it will be in the start of the pulse duration. And how it can be accomplished is fully depending on the counter/timer, which will be counting bottom-up and then overflow directly to zero, this functionality is used for deciding when to set specific output and when to clear it. Explaining it using our project, the requirements were 1 – 2ms duty cycle and 50Hz frequency operation to control the servo motor (from the datasheet), dividing 1 by 50 will produce 20ms which is the total duration, the microcontroller works on 1MHz while the counter 2 in the atmega32 is 16bit which can handle up to 65536 processor tick then overflow, dividing 1MHz by 50Hz will result 20000, this will be the total duration, 20000 is definitely affordable to the 16bit counter which will be configured to work starting from 0 and end at 19999. 1-2ms of 20ms (1/50Hz) is 5% to 10% of the whole duration 20ms, Then 5% to 10% of 20000 is 1000 to 2000 (or actually 999 to 1999 as it starts from 0), the only remained value is the variable which determine the required duty cycle inside this durations which will be calculated based on the mode of PWM operation, in this non-inverted mode 19999 will be the top value and the duty cycle will be floating in the range between 999 and 1999.

The new implementations for robot control required simulation as well as real hardware, and as atmega32 is the most affordable microcontroller in the local market I had to utilize as much as possible its full capabilities. The PWM functionality is provided through two channels, so in order to complete the project I had to extend the functionality of the micro by connecting it to another micro that provide more PWM channels, and for doing so microcontrollers communication protocols has to come to the picture.

Purpose of SPI The reason behind using SPI was the speed in the SPI (up to 10MHz) compared to I2C (400Khz) as the latter is more suitable to multiple higher number of micros applications, and there was no need for USART as it adds more complications of parity bit check, moreover USART doesn’t allow the addition of many chips in case of functionality needed to be extended.

The testing stages were begun using GSM that is used for general purpose data (internet), and after making some tests, 'AT commands' found to be 'unlocked' in that brand, in the same time this kind of GSM modems didn't work with the proteus simulator, investigating a lot in this issue leaded to an assumption that they were echoing issues as well as the mandate for using one of the two important modes (non-canonical mode).

There are two modes of operation in general canonical and non-canonical mode of operation regardless of using Synchronous or Asynchronous, the first is line by line processing edition and deletion is granted, by default the line feed LF or the '\n' new line is the string terminator. The second type is the non-canonical mode which is character by character processing, or else to be more precise this mode depends on two factors/parameters the minimum number of characters and/or minimum timeout before returning the received data.

If MIN > 0 and TIME = 0, MIN sets the number of characters to receive before the read is satisfied. As TIME is zero, the timer is not used.

If MIN = 0 and TIME > 0, TIME serves as a timeout value. The read will be satisfied if a single character is read, or TIME is exceeded (t = TIME *0.1 s). If TIME is exceeded, no character will be returned.

If MIN > 0 and TIME > 0, TIME serves as an inter-character timer. The read will be satisfied if MIN characters are received, or the time between two characters exceeds TIME. The timer is restarted every time a character is received and only becomes active after the first character has been received.

If MIN = 0 and TIME = 0, read will be satisfied immediately. The number of characters currently available, or the number of characters requested will be returned.

Canonical and Non-canonical mode; using this library canonical or non-canonical mode is chosen according to the requirements, actually it adds more complexity to serial communication as it doesn't work with the basic functionality like the embedded C programming libraries. For example to control general purpose GSM modem which is already a popular brand and has it is own user interface API (Application Programmable Interface). So we had to redesign separate code for controlling this modem as the already made interface to the modem will not do the work. The work we need to add is the command detection and process functionality. For instance consider moving the third motor to the left would be expressed with the SMS "$grab:1400#" which will be processed by specific function to split the motor position (which is the grabbing motor) from the movement degree (which is 1400 grabbing degree), the '$' and the '#' character are to define when to start and when the end of the command.

To simulate; after the phase of the testing using Linux and it is standard libraries, Proteus 7.8 is used as a simulator for the solution, so to test the hex file in simulator before applying it in real hardware, in the simulator I had to test each functionality separately, even had to create a simulation and hex files for every and each separate functionality, and that because merely some complexities had arisen when I tried to write the whole code once, soto identify the exact cause of the errors I separated code based on functionality. Using any of the modes to control the third motor will require send the degree though SPI to the slave micro.

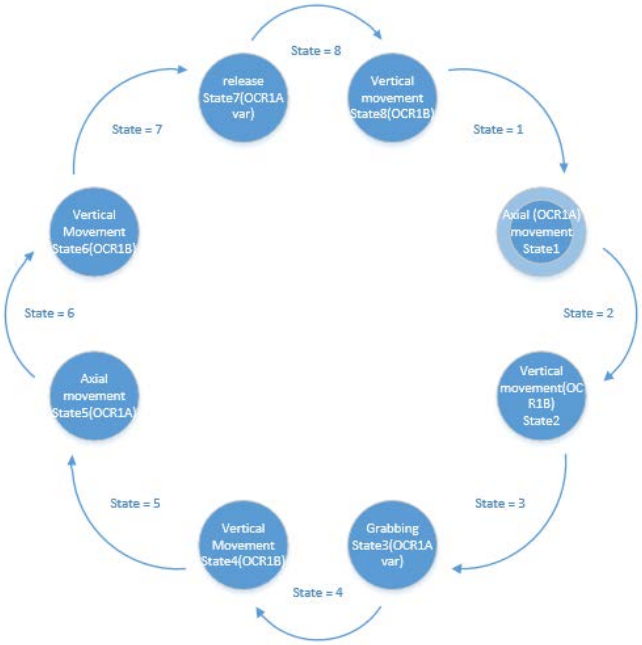

Fig.4 FSM shows the automated mode

This mode has been done in separate executable to provide fully automated control mode or can be called preprogrammed mode.

Fig.7, it shows the connectivity of the two micros as well as the third micro which will represent the GSM modem as it sends data serially same as the GSM modem.

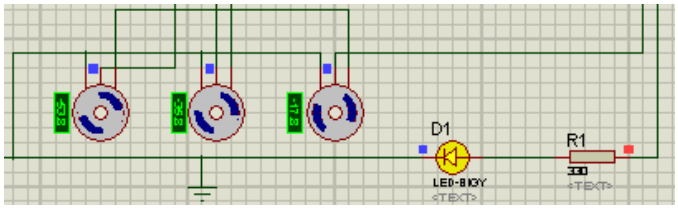

Fig.5 Sending 1200 for the first, 1300 for the second and 1400 for the third motor

Here the three motors are set to specific angles according to the sent commands, which is 1200 for the first motor, 1300 for the second and 1400 for the third. And Fig.6 is virtual terminal that shows the notification message and the sent commands as well.

Fig.6 the SMS notification and received message

4. Conclusion

- The first issue has been partially overcome, by adding variables in the slave code which might affect the performance of the slave but with insignificant effect, same problem could be avoided in the addition of headers, and couldn't be avoided when adding function in the master code.
- Fixing the SPI limitation of one byte, two solutions were used, the first was to divide the value by 10 and multiplying it by 10 in the slave micro, maximum the result will be 299 for 2999 and one byte can hold up to 255, but the limitation of this solution is the loose of fraction as a result rounding up the value.
- Another solution were examined to fix the limitation of the one byte and that was by creating another function to split the integer value into two characters and send them one by one, but again the SPI synchronization arisen.

I recommend I2C to be used instead of SPI protocol in the communication between the microcontrollers. Also work more to accomplish the function of sending and receiving the two bytes command to the third motor as the way used in this research is inefficient due to the drop of the fraction. Mixing the three modes together in one executable will make it very efficient as it will be no need to reprogram it every time, otherwise moving towards the boot loader option is required.

SPI protocol has some synchronization issues, when adding specific number of variables in the Master code, the Slave loose synchronization.

The PWM control values are in the range 999-1999 and obviously these values cannot be assigned to one byte variable, in the same time the third motor has to be controlled via SPI which sends one byte by default. The proposed solution for this was to divide the value by 10 and send it, then after receiving it in the slave micro multiplying it by 10, but this will round up the values with fractions.

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