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ADVANCED CONTROL SYSTEM FOR SYRINGE & INFUSION PUMP USING IoT

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Abstract - Controlled and precise delivery of fluid is one of the essential requirement in many fluid flow applications such as micro fluidics, Micro Electro Mechanical Systems, micro-machining and in medicinal biological systems. Such deliveries are commonly achieved using syringe pump which generally employs syringes driven by an electric motor. In this work a syringe pump is operated with a Raspberry Pi - System on Single Chip, which is more user friendly than a control with an ordinary microcontroller. It runs on Linux platform which is easy to code and control using Python language. The syringe pump is actuated by stepper motor which has 200 steps per revolution so that precise flow rate is possible compared to other electrical actuators. The stepper is connected to a Dual H-Bridge L293D motor driver, which in turn is powered through the GPIO (General Purpose Input / Output) pins – an integral part of the Raspberry pi. Lead screw mechanism is used in this work to transmit rotary motion of the motor to linear motion of syringe. The pitch length travelled by the screw is minimal and controllable, resulting in a precise flow rate of the fluid which is measured experimentally.

I. INTRODUCTION

Syringe Pump finds its applications in various areas such as Healthcare, medical and pharmaceutical industries. In therapeutic centers syringe pump is used in diffusion of drugs through blood which is mainly anaesthetic and hormonal drugs. In PET (Positron Emission tomography) scan, radioactive medicines are injected in to the body through a syringe pump and X-Ray images are taken. In Chemical and process industries, a syringe pump is used for critical titrations where a chemical quantity needs to be more precise. Syringe pumps are also used in micromachining and in places where controlled flow rate is essential. Miller et al [1] designed a modified syringe pump and called it as a High Performance Silicon Pump for drug delivery system. In Ref [2] it was observed that responsiveness of syringe was increased by decreasing the volume of the syringe. Zida Li et al [3] observed that the responsiveness of the syringe pump was affected by fluidic resistance and low flow rate. Appaji et al. [4] worked on single acting Syringe pump control using 8085 microcontroller. In 8085 micro controller debugging and error detection was complex and involved hexadecimal coding system. So in the present work raspberry pi is used which is system on single chip and more versatile than 8085. Actuating mechanisms for syringe pump play a major role in control of the syringe pump. Tarng [6] did a kineto static analysis of lead screw mechanism. In Ref [7] it was observed that linear control of lead screw was possible with low speed devices with precise movements. In lead screw mechanism the motor shaft was connected to a threaded screw and while it turns, it moves the nut forward or backward and also the piston connected with it. Thus the shaft movement governs the delivery of fluid in a controlled manner. The piston generated a hydrostatic pressure, which delivered the fluid into the chamber.

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The cost quoted for syringe pump by New Era Pumps [8] varied from $ 250 - $ 5000. Similar high costs by other companies accelerated the development of systems used in a syringe pump. Because of its applications in various fields, the syringe pump system development is made as open source. Winjen et al [9] has created an Open-Source Syringe Pump library. Kim et al [10] has discussed about a micro fluidic drug delivery system. In this work an attempt has been made to fabricate a syringe pump using Raspberry Pi. The controlling and debugging of the stepper motor used for pumping the syringe is done using open source software Raspbian wheezy using GPIO pins. A stepper motor control is used in this work since minimal flow rate is not possible using a servo motor. Hunting takes place in Servo motor, which distorts the final position of the shaft. If the final position is distorted, more fluid will be released and precise delivery of the fluid is not possible. In case of stepper motor precise control is possible, as shaft moves in steps. The amount of fluid delivered by the pump through experimental method is in good agreement with the predicted theoretical value.

II WORKING OF SYRINGE PUMP

The system consists of a stepper motor, lead screw mechanism, motor controller driver and a Raspberry pi (SOC) with Python programming language for controlling the GPIO pins. Fig. 1 shows the lead screw mechanism used in the present study. The motor shaft is coupled with a nut and screw mechanism. The threads of screw enable the nut to move forward when motor shaft is rotating anticlockwise. The screw rotates in opposite direction during clockwise rotation of the shaft.

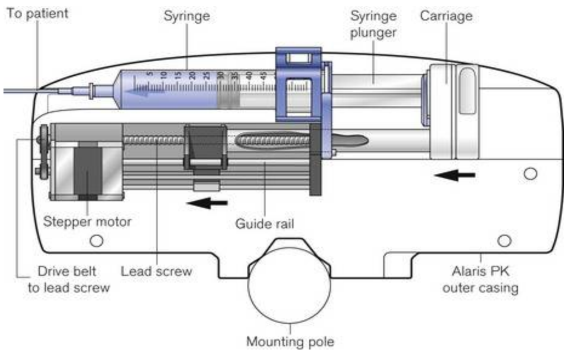

Fig 2.1Parts of Syringe Pump

A Raspberry pi B+ model has been used for controlling the stepper motor. Simon Monk [5] has given a detailed description manual of Raspberry Pi. The pi is a Linux based System on a Single Chip. It runs with an ARM processor with RAM of 512 MB, four USB ports, a VGA pin and a microphone port. It runs on secondary storage expandable up to 32 GB via micro – SD card port. It is powered by secondary source with 5V, 200 mAh. It has 15 functional and 25 GPIO (General Purpose Input Output) pins that can be optionally used as input and output. The user interface used in Raspberry Pi is Raspbian Wheezy, a Linux based Operating System. The programming platform is python which is an Object oriented programming language. It has interpreter which indicates the error while typing and only possible errors are run time errors. The control program is encoded in such a way that the minimum delay between steps of the stepper motor is 10 milliseconds. The Delay is given so that the coil can be energized and de-energized properly.

III WORKING ALGORITHM OF SYRINGE PUMP

Fig. 2 explains the algorithm of the system. The motor driver used in this work is L293D IC (Integrated Circuit), dual H-bridge IC. The controller is programmed in such a way that the number of steps is fed as the input for forward and backward movement. Once the input is given it is processed by the controller and the instruction is then fed to the stepper motor via motor driver. The motor runs and the screw attached with the motor rotate. When the syringe is in extracted position, the bottom of the plunger is placed over the end of the screw. To arrest rotation of syringe, the syringe body is clamped to a frame. Now as the motor rotate, the nut also moves over the screw, and it moves up. Due to this action, the plunger also moves up creating a pressure over the liquid inside the syringe. The speed of the motor can be varied by varying the number of steps and delay time. Instead of L293D, ULN2003AC can also be used.

IV SCHEMATIC LAYOUT OF THE SYSTEM

The schematic layout of the system is shown in Fig. 3 and Fig. 4 shows the experimental setup.

Fig. 4.1 – Schematic Layout

In this work, a syringe mechanism was used to serve as the fluid reservoir and to create the necessary pressure for infusion. It uses an endless worm thread to position the plunger, managing in this way the liquid movement. This process is controlled by a stepping motor where the rotation of the motor is transmitted to the endless thread.

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Normally, a spring is used to push the plunger with a constant force, necessary for a stable infusion pressure. This type of infusion generates a continuous high precision flow (with an error below 2%).

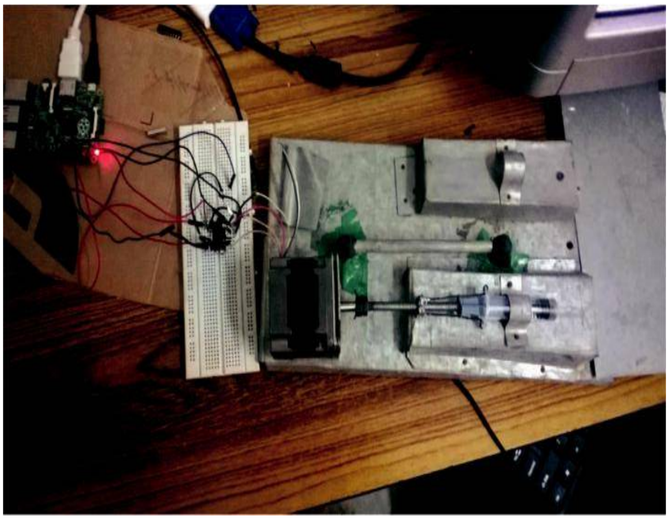

Fig 3 - Experimental setup

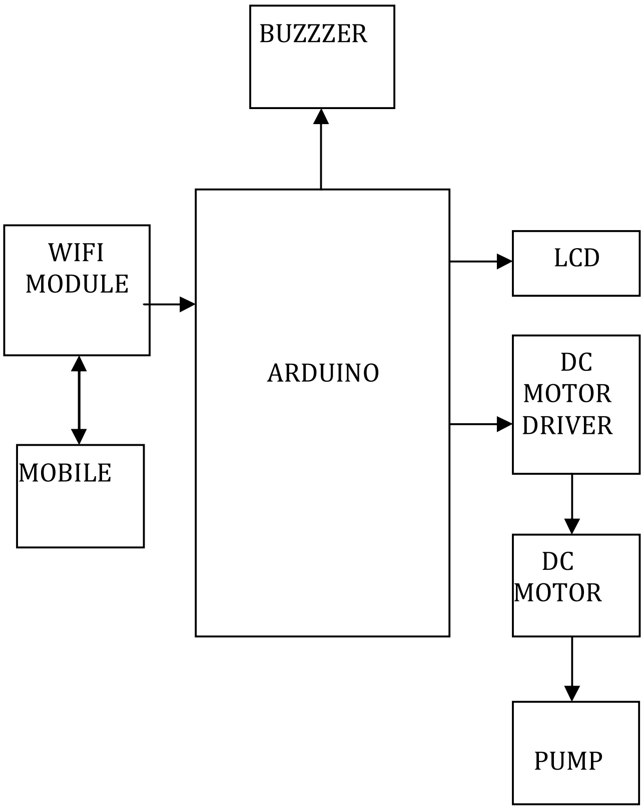

Fig.2.2- Block Diagram

V RESULT AND DISCUSSION

To achieve controlled flow rate, the torque produced by the motor should be minimum and the syringe volume should be less. If the torque is more, flow rate will distort. Volume of syringe affects the fluid pressure inside the syringe and this pressure should be minimal. Fluid flow fluctuation can damage the micro-channel or any other duct which has minimal area. Thus regulating the flow rate is an important aspect. In this work 5 ml syringe and 10 N-m torque motor has been used. In these conditions the flow rate to be achieved is 0.1ml/min. Flow rate is governed by number of steps of the stepper motor. The number of steps is fed as 320. Delay being inversely proportional to flow rate, it should be high. The delay between the steps being used in this work is 10 ms. To verify the experimental results the measured flow rate is compared with the theoretical predictions given by Appaji et al [4] in which the author had predicted the flow in a single acting syringe pump using Bernoulli's theorem.

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The flow rate experimentally measured is around 0.07 ml/min in the present work while the theoretical result predicted by Appaji et al [4] was 0.1 ml/min. The experimental measurement of the volumetric flow rate is done by measuring the fluid collected in a known volume of a container for a known time. Then this container is taken and placed in a precision balance. Enough care is taken in such a way that other dust and impurities present in the container were removed. The difference between the theoretical and experimental value is 0.03 ml/min. To achieve this flow rate the delay between steps has been kept at 10 milliseconds and number of steps being 320. This flow rate has been verified using a precision balance [Shimadzu corporation (AUX220) model- measuring range 220gms with minimal display 0.1mg – linearity 0.3 mg].

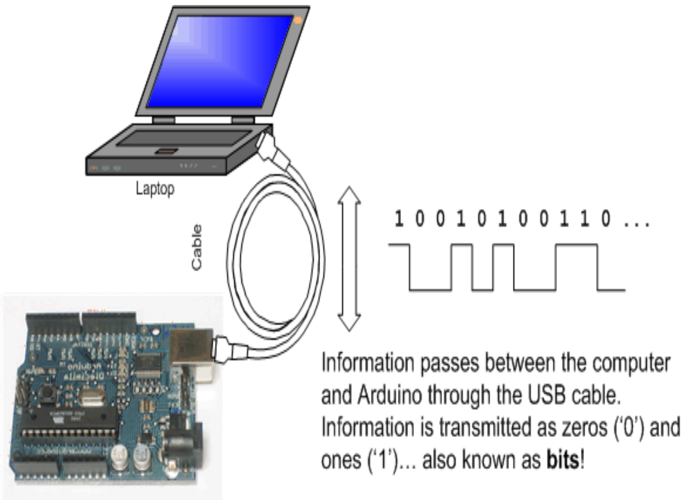

Fig. 5.1 – Interfacing Arduino with Digital System

The flow rate obtained in this work is controlled by varying the speed of the stepper motor i.e. by adjusting the delay between steps and number of steps. In case of 8085microprocessor debugging or modifying the programming interface could have been tedious as it has its own programming architecture, whereas in Raspberry Pi python platform enables user friendly interface. In order to achieve a precise flow rate lead screw mechanism has been used. With these adaptations controlled flow rate is achieved.

VI CONCLUSION

The system developed allows to controlling all the parameters necessary to the syringe infusion pump. The mechanical parts used were part of the original pump but the control hardware and the user web interface was completely designed. Apart from the infusion parameters, all the alarms triggered during an infusion, the battery level – which are parameters related to the equipment, the health professional handling the pump and the medical records related to the patient are also recorded in a database for later information. This system could also be improved, mainly the interface with the mechanical part and the microcontroller, specifically inserting a numerical keypad and a command pushbutton to better control the infusion pump, deal with different syringes for specific volumetric flows, and other aesthetic details. Due to time restraints, more emphasis was given on the development of the connections to the database and remote controlling the pump.

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