Automatic Medical Fluid Infusion System using LabVIEW Real-Time

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ABSTRACT

A syringe infusion pump infuses fluids, medication or nutrients to the circulatory system of the patient. It is generally used intravenously. Syringe infusion pumps can administer fluids in ways that would be impractically expensive or unreliable if performed manually by nursing staff. Advanced versions of these are used in medical applications such as anesthesia injection, during child birth and also to maintain insulin level on a patient. However, they can also be used in non medical applications such as infusion of chemicals, infusion of medicines in aquarium etc…

The primary function of the system is to monitor the temperature, pulse rate and ECG of the patient using National Instrument's LabVIEW and PXI. The system can be used to assist medical personnel by infusing the right amount of medical fluid depending on the patients various physiological parameters thus preventing risk to the patient's life.

General Terms

Infusion System, Medical Fluid, Real Time, LabVIEW

Keywords

Infusion system, Syringe, Body Temperature, Pulse Rate, ECG, LabVIEW Real Time, Medical Personnel, PXI

1. INTRODUCTION

We live in a world where everything can be controlled and operated, but there are still a few important areas where automation has not been adopted or not been put to a full-fledged use, perhaps because of several reasons, one such is the cost.

One such case is in the hospitals, when any major operation is being performed the patient must be in anesthetic condition. If the operation lasts for a long time, say for suppose for 4 or 5 hours, complete dose of anesthesia cannot be administered in a single stroke. It may lead to the patient's death. If lower amount of anesthesia is administered, the patient may not respond as per requirement. To avoid this, the anesthetist administers few milliliters of anesthesia per hour to the patient. If the anesthetist fails to administer the anesthesia to the patient at the particular time interval, other allied problems may arise.

Therefore this work will be a stepping stone towards that goal, this initiative may be considered as the prototype that may be inculcated into such devices which can act as a system that reaches out for further achievement to take place.

Since the process involves human life, failure from the developed system should be avoided. Therefore, there is a strong need for investigating the possibility of designing and implementation of an interactive real-time system which is implemented using LabVIEW and PXI.

2. LITERATURE SURVEY

Ralf Dudde et.al [1] discusses design of insulin infusers meant for patients suffering from diabetes. For a diabetes mellitus patient, tight control of glucose level is essential. Results are reported of an investigation of the suitability of existing wearable continuous insulin infusers controlled and adjusted by a control algorithm using continuous glucose measurements as input to perform the functionality of an artificial pancreas. Dietrich Beck et.al [2] reviews an object oriented approach is used together with LabVIEW RT. Existing object oriented LabVIEW code developed for MS Windows and Linux platforms can be reused on a real-time platform, next to a time- critical loop with high priority.

E.Barrera et.al [3] discusses on Real-Time data acquisition using PXI and also the multiprocessing capability of PXI controller, communication between the controller and processing cards. Real-time data acquisition distribution and dynamic data processing, paper explains the determinism of a system which explains how reliably the system can respond to external system.

Joydeep Bhattacharya et.al [4] reviews the photo-plethysmograph, as a noninvasive device for detecting blood volume changes by optical means. The transmittance type photo-plethysmographic device comprises two infrared (IR)-LEDs (connected in series) as the light source, and two phototransistors (connected in parallel) as the detector.

Akihiko Ichikawa et.al [5] explains the importance of response time and flow rate in designing the syringe pump. Syringe pump for fluid infusion requires high-speed response and high resolution. Voltage supplied to the stepper motor which in turn controls the volume of fluid infused.

3. METHODOLOGY

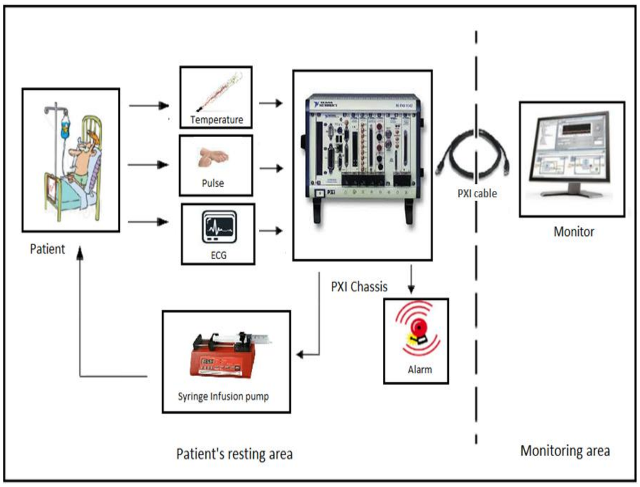

Figure 1: Block diagram of the proposed system

The proposed model [1][4][5] is a user-friendly system, wherein login information is required to access the interface. Patient's database is also provided, wherein the required information can be added or edited. This is provided so as to minimize the confusion and also provides vital information. The system closely monitors the vital parameters like temperature, pulse rate and ECG of the patient. The sensor modules are used to sense the temperature and heart rate of the patient. These signals are connected to the analog input channel of the DAQ. A program is written so as to read and display these signals, after proper signal conditioning. A keypad is provided so as to infuse the fluid at required rate. The keypad control is connected to a sequence generator, which in turn excites the digital output lines of the DAQ. These digital output lines are connected to the terminals of the drive board. The output terminals of the drive board are connected to the stepper motor. The assembly of stepper motor, lead screw, syringe and supporting material forms the infusion pump.

The hardware design is based on the PXI Platform [3] for its ruggedness and multiple analog and digital I/O hardware offerings. A PXI controller running on LabVIEW Real-Time is chosen as the main data acquisition engine. This controller communicates with a host PC through the Ethernet interface.

The Lab VIEW Real-Time Module [2][3] combines Lab VIEW graphical programming with the power of a real-time operating system. It enables us to build deterministic real-time applications. A real-time system ensures that responses occur in time, or on time. Based on this advantage, a high-channel-count data acquisition product that uses Lab VIEW Real-Time to collect and publish data over an Ethernet link is developed. The unit operates like a stand-alone instrument and can be accessed from a host PC using a simple LabVIEW instrument driver.

4. IMPLEMENTATION

4.1 LabVIEW

LabVIEW is a graphical programming language [2][3] designed for engineers and scientists to develop test, control, and measurement applications. The intuitive nature of LabVIEW graphical programming makes it easy for educators and researchers to incorporate the software in a range of courses and applications. With LabVIEW, educators and researchers can use a graphical system design approach to design, prototype, and deploy embedded systems.

4.2 LabVIEW Real-Time

LabVIEW Real-Time [2][3] is a suite hardware and software that allows users to create robust Real-Time systems capable of solving a wide variety of industrial, scientific, control, and monitoring problems. Real-time hardware and software offerings work together seamlessly, providing users with a platform capable of running applications reliably and deterministically with precise timing.LabVIEW Real-Time Module is a graphical programming module that provides users with an easy way to program robust real-time applications.

4.3 PXI

These systems serve applications such as manufacturing test, military and aerospace, machine monitoring, automotive, and industrial test. PXI [2][3] uses PCI-based technology and an industry standard governed by the PXI Systems Alliance (PXISA) to ensure standards compliance and system interoperability.

Most PXI instrument modules are register-based products, which use software drivers hosted on a PC to configure them as useful instruments, taking advantage of the increasing power of PCs to improve hardware access and simplify embedded software in the modules. The open architecture allows hardware to be reconfigured to provide new facilities and features that are difficult to emulate in comparable bench instruments.

4.4 LM35 Temperature Sensor

The LM35 [1][3] series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. LM35 does not require any external calibration or trimming to provide typical accuracies of ±14°C at room temperature and ±34°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level.

4.5 Pulse Measurement

The signal sensing unit [1][3][4] comprises of an LED and LDR arrangement, they are placed facing each other, such that the light of the LED falls directly on the LDR. The second is the signal conditioning unit which uses IC LM358. This IC amplifies and filters the signal obtained from the sensing unit. The output signal from the IC is fed to the analog input channel of the DAQ card.

4.6 Unipolar Stepper Motor

A unipolar stepper motor [1][5] has two windings per phase, one for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (e.g. a single transistor) for each winding. Typically, given a phase, one end of each winding is made common: giving three leads per phase and six leads for a typical two phase motor.

4.7 Lead Screw

A lead screw [1][5], also known as a power screw or translation screw, is a screw designed to translate turning motion into linear motion.

Common applications are machine slides (such as in machine tools), vises, presses, and jacks. Lead screws are manufactured in the same way as other forms. A lead screw can be used in conjunction with split nut.

4.8 Epic Sensor

The Epic Sensor PS25012A1 [1][3] from Plessey Semiconductor is an electric potential sensor which allows the measurement of a wide range of electric potential sources from electrophysiological signals through to spatial electric field. The sensors incorporate a DC block feature that allows the DC component of an applied signal to be rejected while maintaining good low frequency response. The electrode surface of the detector is passivated with a thin dielectric that allows the direct application to a test surface. In the case of contact with skin there is no need for electrically conductive gel.

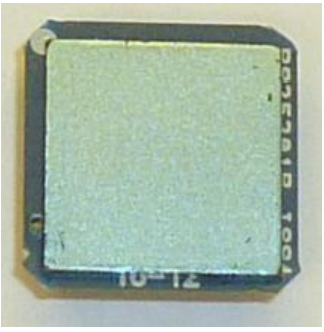

Figure 2: Epic Sensor

The PCB boards onto which the sensor is embedded, provide the regulated +2.5V and generated -2.5V supplies that are used to operate the sensor. This allows the boards to demonstrate the sensors from a wide, single sided, power supply voltage while the output of the sensor can cover the range ±2.1V. The boards are connected by a high reliability five pin connector from which the output signal can be obtained.

5 RESULT ANALYSIS

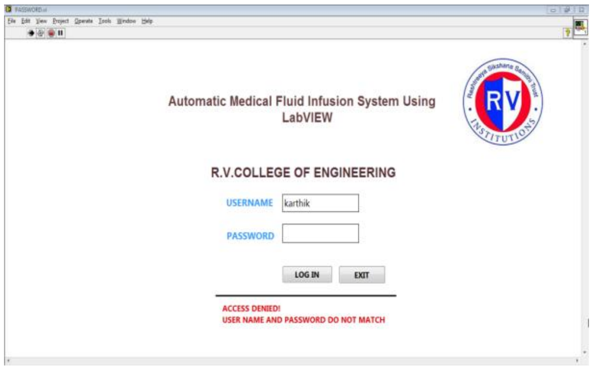

Figure 3: Login Screen window

Login Screen prevents unauthorized user from accessing the application. If a wrong username or password is entered, an "ACCESS DENIED!" message is displayed.

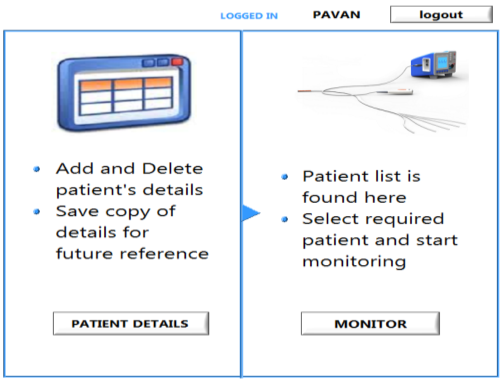

Figure 4: Main Screen window

The main screen window has two parts, patient details and monitor. When using for the first time, it's mandatory to enter the patient details using the "PATIENT DETAILS" option.

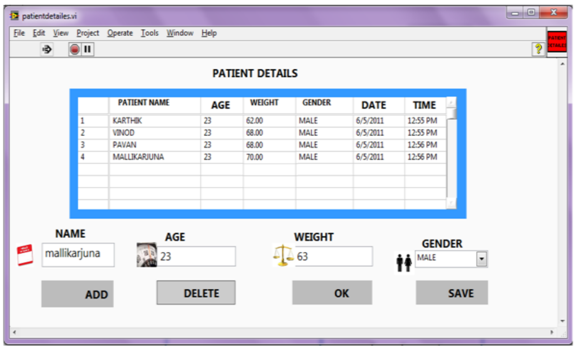

Figure 5: Patient Details window

The 'Patient Details' window pops up when the corresponding button is pressed in the main screen window. The details of patient like age, weight, age, date and time of admission are entered in this window. The patient details first saved using "SAVE" option before pressing "OK" option.

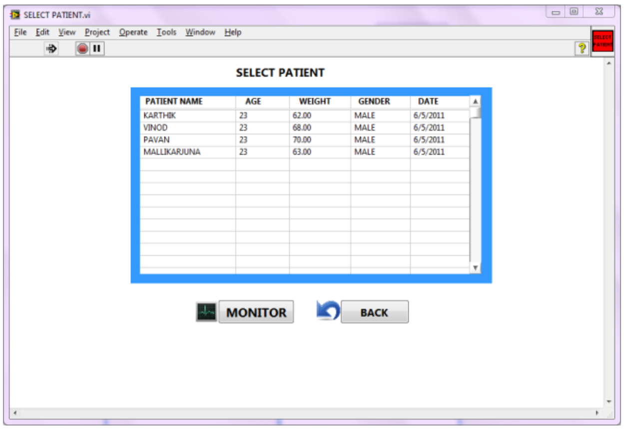

Figure 6: Select Patient window

After the patient details are saved, the control goes back to the Main Screen window. Now the "MONITOR" button is pressed and the control is redirected to the "SELECT PATIENT. Here the required patient is selected and "MONITOR" option is pressed. The patient details which were entered in the 'PATIENT DETAILS' window is automatically updated in 'SELECT PATIENT' window.

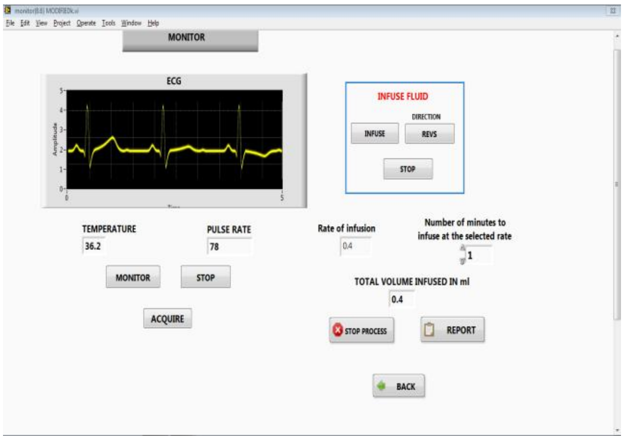

Figure 7: Monitor Window

The Monitor window [1][2] is the main acquisition window, where the patient's parameters are displayed. Acquisition can be started/stopped using suitable buttons on the front panel. Depending on these parameters, medical personnel decide the amount of fluid to be infused. This is achieved by pressing the 'INFUSE' button. Once this is done, 'REPORT' button is pressed to generate the report.

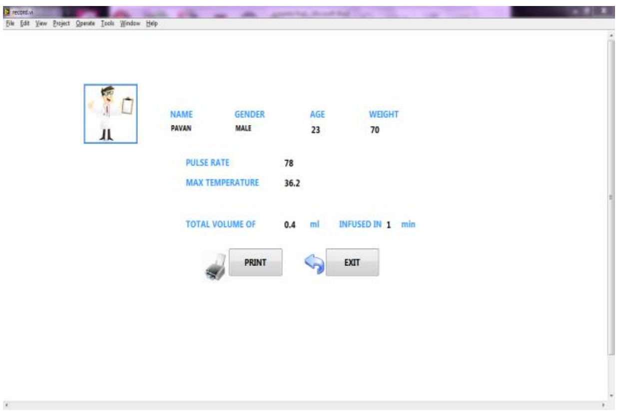

Figure 8: Patient's Report

When the 'REPORT' button is pressed in the monitor window, a report as shown in Figure 6 is generated. Provision to take a print of the report can also be provided.

5.1 Relation between stepper motion and lead screw movement

- The stepper motor requires 200 steps to complete one rotation and 3 rotations of stepper motor infuse 0.2ml of fluid in a 2ml syringe. To infuse 0.4ml of fluid, the stepper motor makes six rotations.
- Lead screw of infusion pump moves 1mm for one rotation of the stepper motor.
- The three rotations of stepper motor correspond to 3mm movement of lead screw that infuses 0.2 ml of fluid.
- By selecting the desired volume and time, infusion can be done at different rate and different span of time.
- The direction of motor is changed using FORWARD or REVERSE button provided in the front panel.

The table describes the stepper motor rotations and Lead screw movement and amount of fluid infused

Table 1: Volume infused and distance moved by stepper motor

Selected Volume (ml)	Selected time(s)	Total volume Infused(ml)	Distance Travelled by Lead screw (mm)	No. of Rotations of Stepper motor
0.4	1	0.4	6	6
0.2	1	0.2	3	3
0.1	2	0.2	3	3
0.05	3	0.15	2.75	2.75

6. PROTOTYPE

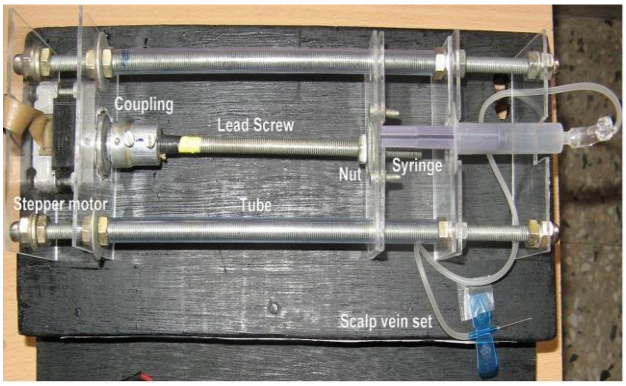

Figure 9: Prototype of syringe pump unit

The heart of the prototype [1][5] is the stepper motor which is driven by the PXI. Lead screw is coupled to the stepper motor which translates the rotator motion of the stepper motor into translator motion. This in turn operates the syringe. A scalp vein set is inserted into the patient's body. Tubing is provided to a smooth motion of the lead screw.

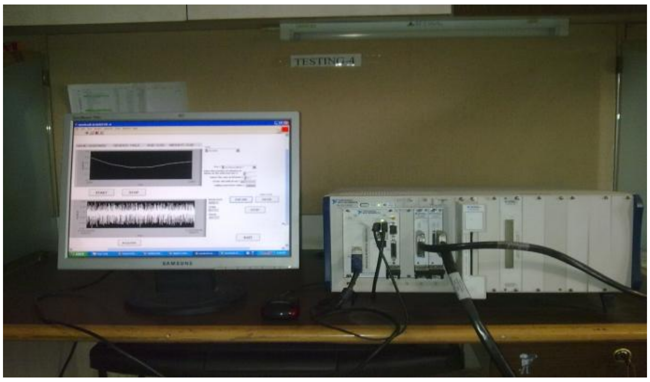

Figure 10: Monitoring Section

Monitoring section [1][3] has the PC running on LabVIEW, which is connected to PXI. The patient's parameters are displayed on the screen.

Figure 11: Patient Bedside

Patient bedside [1][5] comprises of the syringe pump, a terminal box to which all the sensors are connected. This box is connected to the PXI chassis through a cable.

7. CONCLUSION

The use of LabVIEW and PXI makes the whole system more flexible. More parameters can be added to the channels of the PXI DAQ card.

Modern technologies have been developed that promotes comfortable and better life which implies a disease free world. PREVENTION IS BETTER THAN CURE and WHEN EVERY DROP COUNTS FOR LIFE, "Automatic Medical Fluid Infusion System using LabVIEW" is one of the efficient protecting systems.

8. ACKNOWLEDGMENTS

We would like to thank Prof. S. Venkatesh, Ms. Deepashri Devaraj and Mr. Satish Kumar for their support and helping us at various stages.

9. REFERENCES

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