Design and Fabrication of IoT-Enabled Infusion Syringe Pump and Biosensing System for Telemedicine and Healthcare

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Introduction

- An IoT-Enabled infusion syringe pump allows for remote management of patients by caregivers and real time data transfer with little training.
- A wireless connection (ESP8266 wi-fi driver) is required to enable the transmission of operational data to a centralized monitoring system.

- The biosensing technology guarantees patient monitoring and overall health outcomes for patients.
- This system does NOT require patients and caregivers to have any special training to operate it. It's the main goal is to bridge the gap between technological breakthroughs and traditional health care delivery methods.

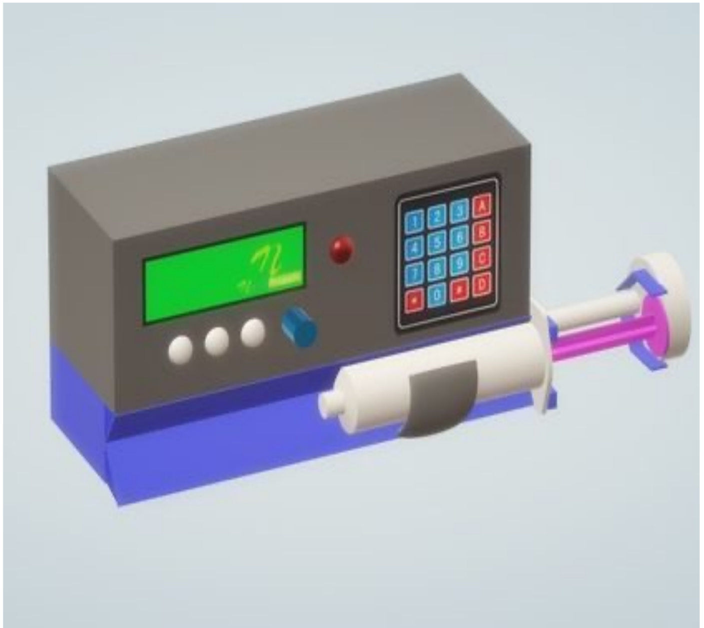
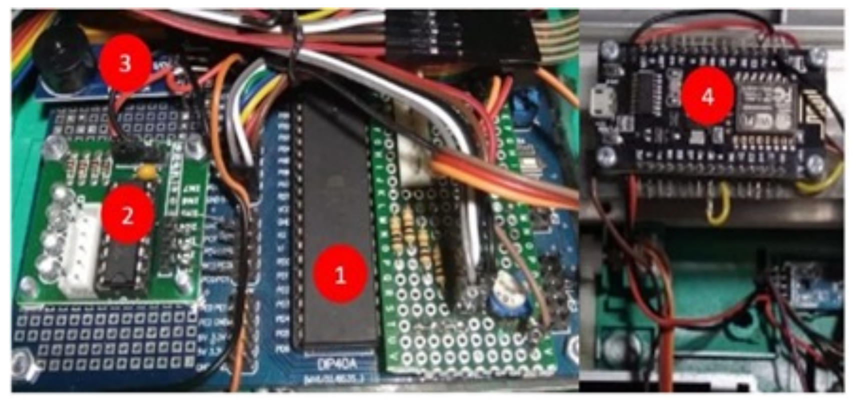


Fig 1: An example of an infusion syringe pump

Background

- The rapid evolution of technologies like telemedicine and IoT has paved way for innovative health care solutions.
- This system employs an Arduino Uno Microcontroller for precise control of stepper motor, ensuring accurate medicine delivery.
- The ESP8266 Wi-Fi module allows for real-time transmission of data of vital signals such as heart rate, blood pressure, and sugar levels.

Fig 2: Arduino Uno Microcontroller



Methods

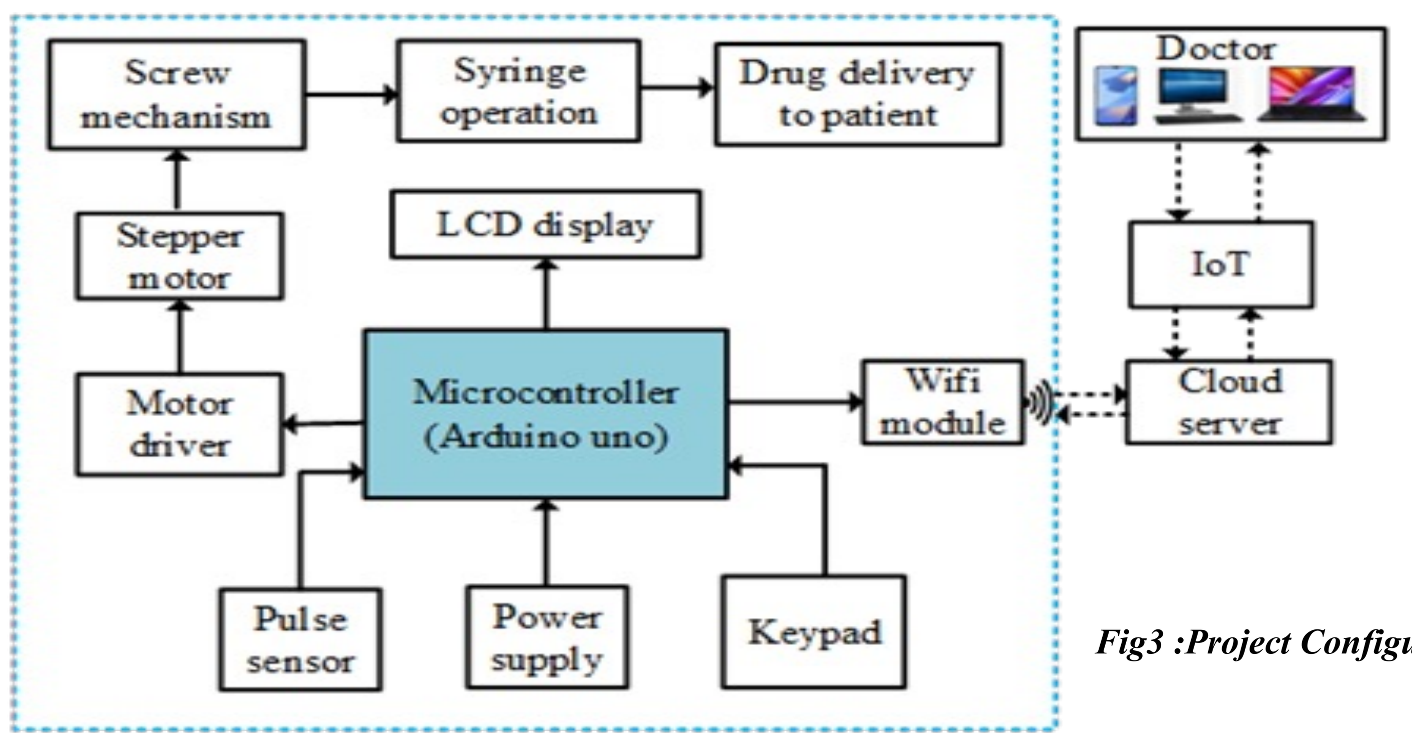


Fig3 :Project Configuration

Method

The IoT-Enabled infusion syringe works under the principles of IoT(Internet of Things) in data transfer, biosensing, Arduino Uno Microcontroller and stepper motors.
The following calculations has to be made:

$$linear\ displacement,(d) = \theta.P$$

Where; θ is the rotational angle of the motor and P = pitch of the ball screw.

$$Thrust\ Force\ (F) = T/(r.\acute{\eta}),$$

Where; T is the motor torque, ή is the efficiency of the ball screw.

$$\Delta d = n.\alpha.P/360$$

Where;
Δd is the change in displacement, n= number of steps, α= angle of the motor.

The DRV8825

The DRV8825 is a microstepping bipolar stepper motor driver by Texas Instruments, known for applications requiring precise control of stepper motors. It is capable of controlling motors in full-step, half-step, and finer microstepping modes (up to 1/32 steps).

Features of DRV8825

- Adjustable Current Control: You can set the maximum current the motor receives by adjusting a potentiometer on the module, which helps prevent motor overheating and increases efficiency.

Microstepping Capabilities: The DRV8825 can control motors in full-step, half-step, and finer microsteps (1/4, 1/8, 1/16, 1/32), allowing smooth movement and finer position control.

Mechanism of ball screw linear guide

The ball screw is chosen due to its less friction therefore leading to a high-performance efficiency as compared to other screws.

The key components include:

- *Ball screw*
- *Ball nut*
- *Linear stepper motor*
- *Inbuilt stepper motor*

The Arduino Uno Microcontroller

This Arduino board integrates easily with other communication modules such as Wi-Fi to permit telemedicine applications.
It also has a built-in USB interface which simplifies programming and data exchange with the computer.
The board is powered by a USB cable connected to an external power source.

Pulse rate calculation:

$$BPM = \frac{60{,}000}{pulseValue}$$

$$stepsToMove = x\ times\ 1000\ steps$$

$$totalTime = \frac{volume(mL)}{flowRate(mL/min)} \times 60{,}000(ms)$$

$$delayTime = \frac{totaltime(ms)}{steps\ to\ move(steps)}$$

- $If\ selectedVolume = 5mL, x = 1.6, 1600\ steps$
- $If\ selectedVolume = 10mL, x = 2.0, 2000\ steps$
- $If\ selectedVolume = 15mL, x = 3.2, 3200\ steps$

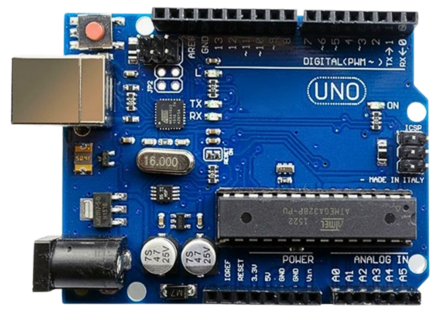


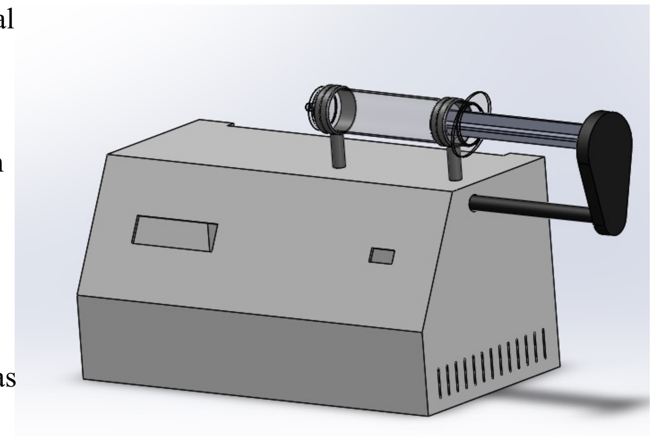
Fig 5: Arduino microcontroller

Results

- The IoT-enabled infusion syringe pump system successfully integrated the Arduino Uno microcontroller, ESP8266 Wi-Fi module, and biosensor. The prototype effectively monitored and transmitted patients' vital signs including heart rate.
- The data obtained from the sensor was sent to the cloud for monitoring and analysis purposes.
- Operating the system was very easy for both patients and caregivers as the remote monitoring and management was very effective.

Discussion

- The ball screw linear guide provided precise linear motion, which is crucial for the accurate administration of medication.
- The minimal friction and high efficiency (90% + 95%) of the ball screw significantly contributed to the systems reliability.
- The use of ESP8266 Wi-Fi module allowed for real time data transmission to other health care professionals. This enables for remote monitoring and adjusting, reducing the need for constant bedside attendance and allowing health care providers to manage multiple patients more efficiently.
- Integrating telemedicine capabilities in the infusion pump system bridges the gap between the modern technology and traditional health care delivery. Patients in remote areas can now receive the same level of care as those in urban areas.
- The Blynk interface enables a simple interface which ensures that patients and caregivers can operate the system with minimal training.



Summary, Conclusions and Future Directions

The IoT-enabled infusion syringe pump with integrated biosensors represents a transformative advancement in healthcare management. Combining precision, efficiency, and remote monitoring, it enhances the accessibility and quality of care, especially for underserved and remote areas. This project focused on incorporating a heart rate sensor, but future enhancements could include additional biosensors to monitor a broader range of vital signs, further optimizing patient outcomes. Advancements such as expanded sensor capabilities, AI-driven analytics, and improved energy efficiency will pave the way for wider telemedicine adoption, redefining healthcare delivery and bridging the gap between technology and traditional care methods.

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