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Artículos Científicos

Sistema de monitoreo electrónico de asfixia neonatal

Neonatal Asphyxia Electronic Monitoring System

Sistema de monitoramento eletrônico de asfixia neonatal

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Resumen

El síndrome de muerte súbita del lactante (SMSL) es una de las principales causas de muerte encontradas en las autopsias a bebés menores de un año. Aunque se han identificado múltiples factores de riesgo estadísticos, científicamente no hay certeza de qué provoca este trastorno. Por ello surge la idea de crear un dispositivo de monitoreo para medir las pulsaciones del lactante, capaz de emitir una alerta cuando se presente un problema respiratorio en bebés lactantes y así prevenir el SMSL. El método utilizado fue el del análisis. El dispositivo está compuesto por sensores piezoeléctricos, un microcontrolador, látex y cables. Para la producción del dispositivo, fue necesaria una máquina de prototipado de placa de circuitos impresos (PCB, por sus siglas en inglés). Con este proyecto se presenta una forma de monitorear los pulsos cardiacos del lactante: al detectar un ritmo diferente al normal, mediante el uso del internet de las cosas (IdC), emite de inmediato una notificación. Además, presenta tecnología *open hardware* y *software* de Arduino. Como se utiliza tecnología abierta, los usuarios tienen la posibilidad de mejorar el diseño o añadirle nuevas funcionalidades. Se trata de una muestra de que este tipo de tecnologías se pueden utilizar como herramientas de prevención en el campo de la medicina, en este caso, para prevenir la muerte súbita del lactante.

Palabras clave: dispositivo, lactante, monitoreo.

Abstract

Sudden infant death syndrome (SIDS) is one of the leading causes of death found at autopsies in infants under one year of age. Although multiple statistical risk factors have been identified, scientifically there is no certainty of what causes this disorder. Hence the idea to create a monitoring device to measure the pulsations of the infant, capable of emitting an alert when a respiratory problem occurs in nursing babies, and thus prevent SIDS. The method to be used is the analysis. The device is composed of piezoelectric sensors, a microcontroller, latex and cables. For the production of the device, a printed circuit board (PCB) prototyping machine was necessary. This project presents a way to monitor the infant's heart rate: detecting a different rhythm than normal, using the Internet of Things (IoT), immediately issues a notification. In addition, it features open hardware and Arduino software technology. Since open technology is used, this allows users to improve the design or add new functionalities. It is a sample that this type of technology can be used as prevention tools in the field of medicine, in this case, to prevent sudden infant death.

Keywords: device, infant, monitoring.

Resumo

A síndrome da morte súbita do lactente (SMSL) é uma das principais causas de morte encontradas em autópsias de bebês menores de um ano de idade. Embora vários fatores de risco estatísticos tenham sido identificados, não é cientificamente certo o que causa esse transtorno. Por isso, surgiu a ideia de criar um dispositivo de monitoramento para medir a frequência cardíaca do bebê, capaz de emitir um alerta quando ocorre um problema respiratório em bebês amamentados e, assim, prevenir a SMSL. O método utilizado foi o de análise. O dispositivo é composto por sensores piezoelétricos, microcontrolador, látex e cabos. Para a produção do dispositivo, foi necessária uma máquina de prototipagem de placa de circuito impresso (PCB). Este projeto apresenta uma forma de monitorar os pulsos cardíacos do bebê: ao detectar um ritmo diferente do normal, por meio do uso da Internet das Coisas (IoT), ele emite imediatamente uma notificação. Além disso, possui tecnologia aberta de hardware e software do Arduino. Com a utilização de tecnologia aberta, os usuários têm a possibilidade de aprimorar o design ou adicionar novas funcionalidades a ele. Isso é um exemplo de que esse tipo de tecnologia pode ser utilizada como ferramenta de prevenção na área da medicina, neste caso, para prevenir a morte súbita de bebês.

Palavras-chave: dispositivo, bebê, monitoramento.

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Introduction

Sudden Infant Death Syndrome (SIDS) is the death of an apparently healthy baby under one year of age. It usually happens during sleep. This disorder is sometimes referred to as crib death because infants typically die in their cribs, as mentioned above (Mayo Clinic, February 5, 2019.

Although the cause is unknown, SIDS may be related to defects in the portion of the baby's brain that controls breathing and return to wakefulness.

According to the Mayo Clinic website (February 5, 2019), experts in the field have discovered some factors that could put babies at even greater risk and have identified some measures to prevent SIDS. Among the latter, perhaps the most important, is to place your baby on her back to sleep.

Rachel Moon (2016) notes that the distinction between SIDS and other sudden and unexpected deaths in infants (SUIDs), particularly those that occur during a period of unobserved sleep (sleep-related infant deaths), such as involuntary suffocation is challenging, cannot be determined by autopsy alone, and may remain unresolved. After a full investigation of the case, many of the modifiable and non-modifiable risk factors for SIDS and asphyxia are strikingly similar (Moon, 2016, p. 2).

Recently, the Apno Systems company has developed a wristband that tries to prevent sudden deaths and whose main mission is to control the baby's oxygen and heart rate. The wearable, which they have dubbed the Infant Care System, in the case of detecting an abnormality in the child's vital signs, emits an alarm that reaches the parents' smartphone directly so that they can act quickly. In addition, the wristband emits a small shock on the baby's body in order to restore normality in the child's vital signs (Cid, 30 de marzo de 2016).

Materials and methods

Detection of need

Data from the Centers for Disease Control and Prevention (CDC) show that in 2010 (the most recent year for which data is available) 2,063 children died of SIDS, also known for its acronyms in English, such as SIDS (Murphy, Xu and Kochanek, 2013, cited in Office of Communications, January 21, 2015)

The device in question will communicate via Wi-Fi to a smartphone application, thus avoiding interruptions between the devices. In addition, it will have an accessible cost for the target market. The product is aimed at parents with neonatal children, prone within the first 11 months of life to suffer from cradle death. The design consists of a monitoring device to measure the infant's heart rate and prevent SIDS.

Following Medina (September 17, 2015), “the rapid heartbeat of a newborn baby is normal. While the rate of an adult is 60 to 80 beats per minute (bpm), that of babies is usually between 120 and 160 bpm ”(para. 4). At one month of birth, it usually presents from 100 to 150 bpm; at two years, between 85 and 125 bpm; at four years, from 75 to 115 bpm; at six years, from 65 to 100 bpm, and those over six years, from between 60 and 100 bpm (Medina, September 17, 2015). “The heart of the little ones beats more frequently because it is still immature” (Medina, September 17, 2015, para. 4).

The method to be used is that of analysis. The device is made up of piezoelectric sensors, a microcontroller, latex, and cables. As for the former, “the piezoelectric sensor can be made up of ceramic materials or ionic crystals that are capable of generating a small electrical energy when they are deformed. This effect is known as the piezoelectric effect ”(Mecafenix Engineering, July 3, 2018). Therefore, for the production of the device, a printed circuit board (PCB) prototyping machine is necessary.

The following was used to make the instrument:

1) NodeMCU development board with ESP8266 wifi chip.

2) Heart rate sensor.

3) Buzzer.

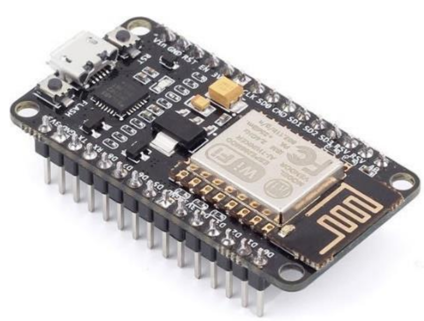
4) Arduino IDE.

5) Blynk for mobile.

NodeMCU ESP8266

ESP8266 is the name of a microcontroller designed by a Chinese company called Espressif Systems, based in Shanghai. Its mass production dates back to the beginning of 2014, when it was announced that this chip would be an excellent solution, a bridge for those microcontrollers that needed to connect to a Wi-Fi wireless network (Ceja, Rentería, Ruelas and Ochoa, 2017, pp. 24-36) (see figure 1).

Figura 1. NodeMCU ESP8266



Fuente: 330ohms (s. f.)

Heart rate sensor

The pulse sensor amplifies the raw signal from the previous pulse sensor and normalizes the pulse wave around V / 2 (midpoint in voltage) responding to relative changes in light intensity (Bolaños, June 29, 2018, p. 3) (see figure 2).

Figura 2. Sensor de pulso

Fuente: World Famous Electronics llc. (s. f.)

Table 1 shows the specifications of the sensor connection.

Tabla 1. Conexión del sensor

NodeMCU	Sensor
3.3 V	+VCC
GND	-GND
A0	S

Fuente: Elaboración propia

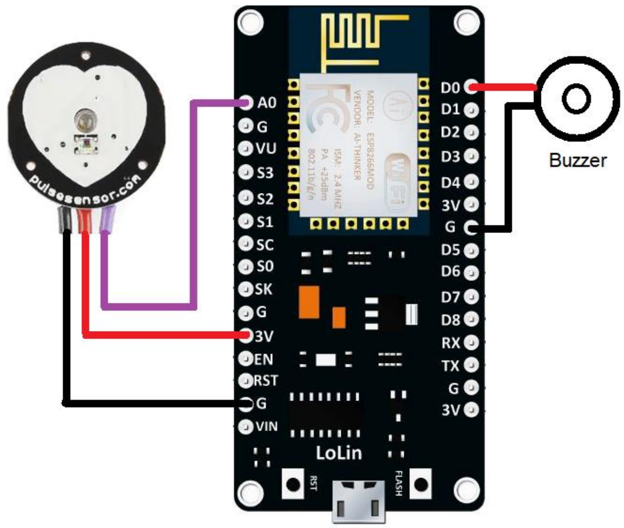
Arduino IDE

The Arduino IDE is a programming environment that has been packaged as an application program; that is, it consists of a code editor, compiler, debugger, and graphical interface (GUI) builder. It also incorporates the tools to load the already compiled program into the hardware flash memory (AprendiendoArduino, 2018).

Buzzer

It is an electrical signal apparatus that makes a buzzing sound (Merriam-Webster., s. f.) (Véase figure 3).

Figura 3. Buzzer



Fuente: Elaboración propia

Blynk for mobiles

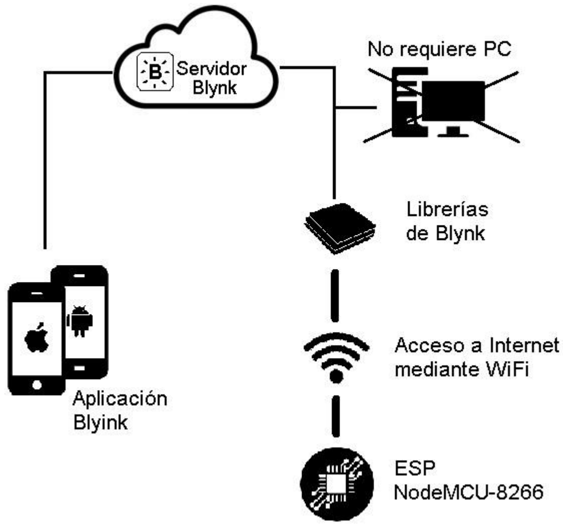
It is an Internet of Things (IoT) platform for Android and iOS to control systems developed with Arduino and Raspberry Pi (Humanized Technology, November 6, 2018).

Many IoT applications require the following:

> Massive data storage, high processing speed to enable real-time decision-making, and high-speed broadband networks to transmit data, audio or video. Cloud computing offers the ideal solution for handling huge data streams and processing for an unprecedented number of IoT devices and humans in real time (Salazar y Silvestre, 2016, p. 25)

The operating architecture is illustrated in Figure 4.

Figura 4. Blynk para móviles



Fuente: Elaboración propia

The IoT grows and scales thanks to the technology or wireless sensor networks (WSN), and plays an important role in the communication of all networks, that is, in the ubiquity of these (Cera, Mart, Rojas, Villaveces y Sanmart, 2015, p. 2).

Code for programming in ESP8266 NodeMCU

The programming was done with the Arduino sketch structure. In this same interface the necessary libraries are added to be able to work the ESP8266 board, as if it were in Arduino programming. See figure 5, 6 and 7.

Figura 5. Librerías (parte uno)

```
/*Código para la placa ESP8266 NodeMCU
* se toma como dato que los latidos normales
* del bebe son de 70 a 190
* Por debajo o arriba de esta cantidad, el sistema
* realiza la función de enviar alarma
*/

#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

char auth[] = "colocar aquí el Token de Blynk";    // Token que genera Blynk
char ssid[] = "xxxxxx";                            // Aquí se coloca el nombre de la red WiFi
char pass[] = "xxxxx";                             // Aquí se coloca la contraseña de la red WiFi

int UpperThreshold = 518;
int LowerThreshold = 490;
int reading = 0;
float BPM = 0.0;
bool IgnoreReading = false;
bool FirstPulseDetected = false;
unsigned long FirstPulseTime = 0;
unsigned long SecondPulseTime = 0;
unsigned long PulseInterval = 0;
const unsigned long delayTime = 10;
const unsigned long delayTime2 = 1000;
const unsigned long baudRate = 9600;
unsigned long previousMillis = 0;
unsigned long previousMillis2 = 0;
int alarma = 0;

void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass);
  pinMode(13, OUTPUT);
  digitalWrite(13, LOW);
```

Fuente: Elaboración propia

Figura 6. Librerías (parte dos)

```
}

 void loop(){

  Blynk.run();
Blynk.virtualWrite(V0,BPM);

// Toma el tiempo actual
    unsigned long currentMillis = millis();

    // Primer evento
    if(myTimer1(delayTime, currentMillis) == 1){

      reading = analogRead(0);

      // Pulso cardiaco alto detectado
      if(reading > UpperThreshold && IgnoreReading == false){
        if(FirstPulseDetected == false){
          FirstPulseTime = millis();
          FirstPulseDetected = true;
        }
        else{
          SecondPulseTime = millis();
          PulseInterval = SecondPulseTime - FirstPulseTime;
          FirstPulseTime = SecondPulseTime;
        }
        IgnoreReading = true;
        digitalWrite(13, HIGH);
      }

      // Pulso cardiaco bajo detectado

      if(reading < LowerThreshold && IgnoreReading == true){
        IgnoreReading = false;
        digitalWrite(13, LOW);
      }

      // Calcula los pulsos por minute
```

Fuente: Elaboración propia

Figura 7. Librerías (parte tres)

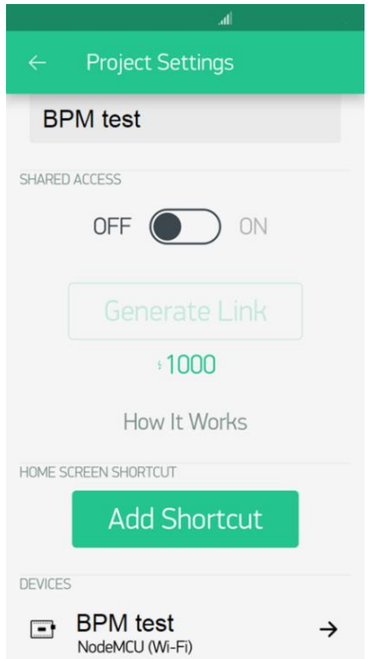
```
BPM = (1.0/PulseInterval) * 60.0 * 1000;
    Blynk.virtualWrite(V0,BPM);
    if(BPM < 50){
     int alarma = alarma + 1;
     if(alarma > 5){

    //información usada en prototipo
     Blynk.email("jasoberon@gmail.com", "Baby Care Alert", "BPM bajo!");
       int alarma = 0;
     }
    }
   }
   // Segundo evento

   if(myTimer2(delayTime2, currentMillis) == 1){
    Serial.print(reading);
    Serial.print("\t");
    Serial.print(PulseInterval);
    Serial.print("\t");
    Serial.print(BPM);
    Serial.println(" BPM");
    Serial.flush();
   }
}
// temporizador del primer evento
int myTimer1(long delayTime, long currentMillis){
   if(currentMillis - previousMillis >= delayTime){previousMillis = currentMillis;return 1;}
   else{return 0;}
}
// temporizador del segundo evento

int myTimer2(long delayTime2, long currentMillis){
   if(currentMillis - previousMillis2 >= delayTime2){previousMillis2 = currentMillis;return 1;}
   else {return 0;}

}
```

Fuente: Elaboración propia

Application settings in Blynk

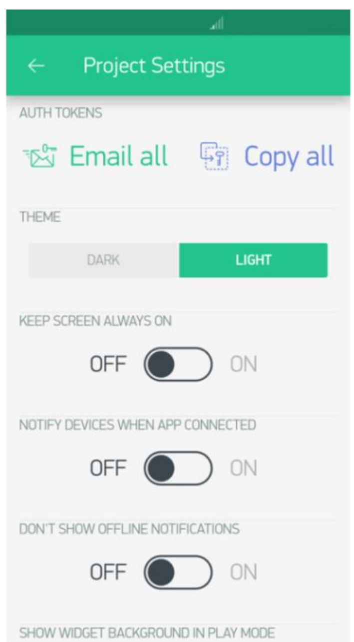
Below are the steps to follow to configure the application on a cell phone using Blynk, which will serve as a visual monitoring part of the device. (See figure 8 and 9)

Figura 8. Vistas Android



Fuente: Elaboración propia

Figura 9. Vistas Android



Fuente: Elaboración propia

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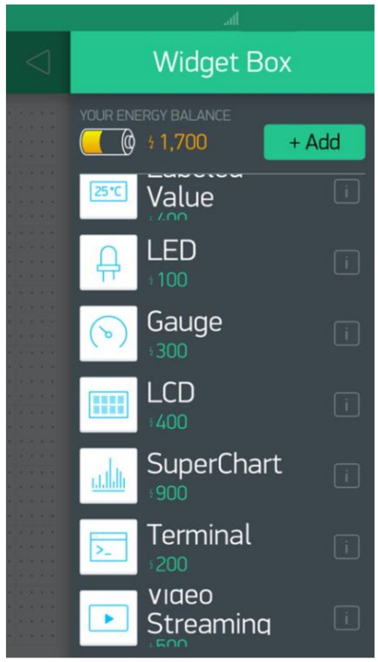
Indicators

At this point, we select the Gauge indicator. See figure 10.

Figura 10. Indicadores

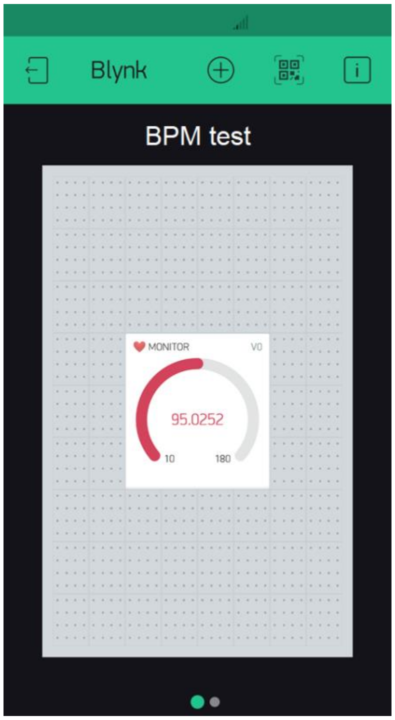


Fuente: Elaboración propia

Dashboard in edit mode. Organization and configuration of the indicator

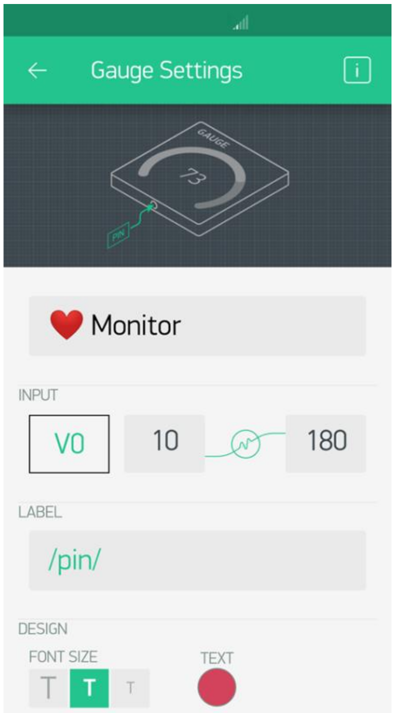
Figures 11 and 12 show the configuration of the indicator in the application.

Figura 11. Configuración del indicador en la aplicación



Fuente: Elaboración propia

Figura 12. Vistas Android



Fuente: Elaboración propia

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The ADC0 indicator will take the given reading of the signal conditioning from the pulse per minute (BPM) sensor. The settings are scaled from 0 to 200 points, with a real-time update of two seconds per sample.

Visual dashboard working on a cell phone with the application configured in Blynk

Next, the final presentation of the application in Blynk is shown in figure 13 and 14

Figura 13. Tablero visual en línea

Fuente: Elaboración propia

The cell phone, of any brand, is now our dashboard and the means for smart power management and increased equipment life (Chávez y Vega, 14 de agosto de 2019).

Figura 14. Dashboard en línea

Fuente: Elaboración propia

Financial study

The internal rate of return (IRR) is the interest or profitability rate generated by a project (Restrepo, 2017). It is provided with an investment of 5,000 Mexican pesos. The cost of the prototype device is 300 pesos. The production cost for five devices assembled on a single board using only one input pin of the ESP8266 board and coupled with the BPM sensor is approximately 2000 pesos in an external company dedicated to this manufacture. For higher production, the price decreases. The amount of sales that should be made to recover the investment cost will be at least four devices. The capital ratio comes from an own investment.

The pricing strategies for the device are of the incremental type, setting a base cost above the cost of production. The cost will be adjusted with respect to the cost of the competition.

Results

With an Arduino Uno board, simulations of cardiac pulses were programmed in the form of analog data ranging from the values of 10 to 180 pulses per minute. This data was sent in the form of serial communication between the Arduino Uno used as a simulator and the prototype using the ESP8266 NodeMCU board. As a first test, simulated sequences of normal heart pulses were performed for a continuous period of five minutes. It was observed that the prototype responds correctly in real time; only when sending the data to the cloud, through the Blynk application, there is a delay that varies from one to two seconds in displaying the information. In a second test, a normal sequence of heart pulses was generated for one minute and then sent pulses below and above normal that could occur in babies. The response was satisfactory, since the prototype alarm was turned on, as well as the alarm signal sent through the cloud through the Blynk application.

With this information we were able to demonstrate correct operation. Although there is the issue of communication delay outside the device, this does not affect, since the alarm is activated locally, and the alarm to the remote device is raised with approximately one second of delay.

An improvement that can be made in the future is to reprogram using artificial intelligence. This is due to the fact that false alarms could be presented with some sudden movement of the baby, when kicking, turning around or experiencing any change in their vital signs that are not harmless.

Discussion

The innovation that is being carried out is incremental, since there are already other very similar versions, such as the one offered by the company Apno Systems. The prototype presented is functional and easy for parents to interpret: as soon as a problem arises that may compromise the baby's health and must be attended to as soon as possible. In addition to the fact that it is suitable to be accessible in the market in which it will be introduced (more economical wearable type presentation). The level in which the prototype is currently is dissociative because the innovations that it has are in some of its components. The product is viable since it presents an economic solution that no one offers in our region to this syndrome.

Conclusions

This project presents a way to monitor the infant's heart pulses: upon detecting a different rhythm than normal, through the use of the IdC, it immediately issues a notification. In addition, it is presented with Arduino open hardware and software technology. As open technology is used, users have the possibility to improve the design or add new functionalities to it. This is an example that this type of technology can be used as prevention tools in the field of medicine, in this case, to prevent sudden infant death.

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