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DESIGN AND CONSTRUCTION OF A PID CONTROL FOR THE PREVENTION OF SUDDEN INFANT DEATH SYNDROME THROUGH THE USE OF THE RASPBERRY PI PICO CARD

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Abstract: Sudden infant death syndrome or better known as crib death, is the death that a baby usually suffers when they are asleep and have an interruption in air absorption because they do not yet have adequate control of their respiratory response. This project consisted of the design and construction of a control system that allows to detect when a baby in a crib is at risk of suffering the crib death. The designed control allows to control a mechanism with servo motors that will move to the crib so that the baby returns to a safe position. An important part of this project is the design of the PID Control Circuit that includes a Kalman Filter that will allow more effective control of the movement of the crib where the baby is sleeping. An accelerometer will detect the position of the baby in her crib and allow it to determine when the baby has been placed in a sleeping position that could cause crib death. When this happens, the corresponding control will be activated by means of servomotors placed at the base of the cradle to return it to a suitable position where there is no such danger. The device will also emit an audible alarm so that the parents or people close to the baby act accordingly. The microcontroller card used is the Raspberry Pi Pico. Tests were carried out on newborn babies to confirm the functionality of the designed device in terms of returning the baby to a suitable position for breathing when the baby's movement put this function at risk.
Keywords: Sudden infant death, airway obstruction, accelerometer, servomotors, Raspberry Pi Pico.

INTRODUCTION

Sudden Infant Death Syndrome or commonly known as "Crib Death", is the death of an infant under one year of age due to the infant stopping breathing apparently without cause [9].

This occurs when babies are asleep and have interrupted air absorption due to inadequate breathing control.

Babies who are more likely to suffer from this type of syndrome are those whose mothers are teenagers or older than 40 years of age.

There is a large increase in this syndrome if the baby for some reason is exposed to cigarette smoke or was born prematurely, although this does not rule out that healthy babies do not suffer from sudden infant death syndrome, since sleeping on the stomach or very tucked in can also cause the passage of air to be interrupted and lead to fatal outcomes [1].

To avoid or prevent crib death, in most cases; just straighten the baby. This movement will cause the baby to breathe again. It is quite difficult to detect crib death when the baby is sleeping.

In this project, knowledge from the area of mechatronics is used to design and build a PID (Pro portional, Integral and Derivative) to control servomotors to move the cradle where a baby is sleeping to prevent the baby from adopting a position where its respiratory tracts could become obstructed and thus endanger its life.

The position of the baby is detected by a device known as accelerometer that together with the Raspberry Pi Pico microcontroller card will activate 4 servomotors located at the base of the cradle that will move the cradle so that the baby returns to a position where the obstruction of its of its respiratory tracts is not in danger.

Therefore, this project tries to find, through principles and knowledge of PID Control and filtering, to attack a real problem such as Sudden Infant Death Syndrome (Crib Death). This project seeks to ensure that a baby can sleep without problems and in the event that the baby is in a dangerous position, the cradle where the baby is automatically moves and emits an audible signal to be heard by people who are close to act and thus prevent the baby from dying.

OBJECTIVE

GENERAL

To prevent and avoid newborn babies dying from the so-called "Crib Death" also known as Sudden Infant Death Syndrome.

PARTICULAR

Design and build PID Control for a device to emit an audible signal and control the movement of a cradle when a baby is detected to be in a position that puts it at risk of suffering the so-called "crib death".

DESCRIPTION

In order to prevent babies under one year of age from dying due to the so-called "Crib Death", the PID control of a mechanism was designed to make a crib swing in the opposite direction to the baby's movement in order to prevent the baby from being placed in a sideways or upside-down position. The mechanism is mainly conformed by 4 servomotors with a torque of 60 Kg/cm at 180° to perform a movement opposite to the one the baby would perform [8]. Figure 1 shows a simplified schematic of this.

Figure 1. Diagram showing the idea of using servomotors in the cradle.

If the baby were to be placed in a face-down position, the device would activate the servomotors located at the base of the cradle to move it and return the baby to a safe position, and it would also emit an audible signal for people near the baby to take immediate action [7].

To achieve all of the above, the appropriate electronic components were required to perform the desired function. The idea was to use the least number of electronic components and to keep them as small as possible so that the device could be placed on the baby without causing discomfort or harming it.

The microcontroller board selected to be the brain in this project was the Raspberry Pi Pico which is about 6 times faster than an Arduino uno. The Raspberry Pi Pico board is small with powerful programming functions that are necessary to perform the PID control efficiently and quickly and Kalman filter calculations [2].

To detect the position of the baby, the MPU6050 inertial measurement unit with 6 degrees of freedom is used, which has an accelerometer and a gyroscope. To emit the audible alarm, a buzzer and a programming routine were used to allow the emission of a sound every 0.5 seconds[5].

The main electronic devices used for the development of the Project are shown below in Figure 2.

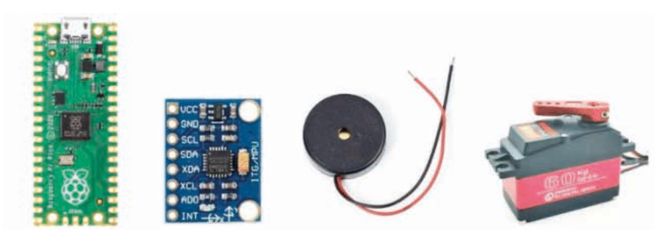

Figure 2. From left to right: Raspberry Pi Pico, MPU6050, Buzzer, Servomotor.

The Raspberry Pi Pico microcontroller board was programmed using the Thonny IDE which has Phyton 3.10 built into its interface [6].

The servomotors used have a torque of 60 Kg/cm which together will move the cradle with a newborn baby that could vary its weight from 3 Kgs when it is born to 8 Kgs when it is

6 months old.

Remember that the highest probability of "Crib Death" happening in a baby is from birth to approximately 6 months old.

The following figure shows the connection diagram of the main electronic components used.

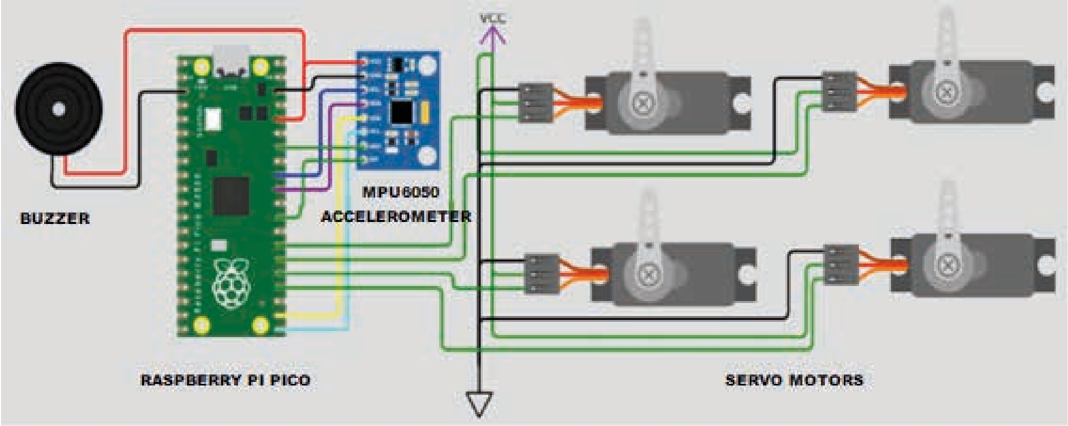

Figure 3. Connection diagram of the main electronic elements.

Since the baby's cradle will be controlled to return the baby to the face up position, servomotors were used to control the corresponding mechanism. The PID Control together with the Kalman Filter will act on the servomotors to correct the position of the cradle.

The operation of our device is simple, the accelerometer is a sensor of the type that cell phones use to detect the orientation of the screen depending on whether we place the cell phone vertically or horizontally. The previous principle is used to determine the position in which the baby is.

If the position is such that the baby is at risk of not breathing, a control mechanism will be activated that will allow the cradle to move in a direction opposite to that in which the baby is moving in order to return it to its original position. In addition, an audible alarm will be activated to indicate the situation so that the baby's parents can act immediately.

METHODOLOGY

-PID CONTROL

An essential part of enabling the baby to return to a safe position once he or she has moved to the side or face down is the crib's motion control mechanism.

This mechanism will be controlled by a PID Type Control (Proportional, Integral and Derivative Control) in parallel configuration [10], whose block diagram is shown below.

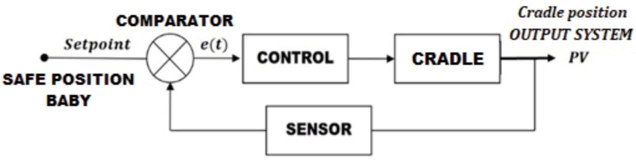

Figure 4. Block diagram for control of the cradle mechanism.

In this diagram, it is clearly seen that the PID Controller will act on the cradle mechanism to place it in a position that allows the baby to return it to a safe position.

The structure used for the design of the PID Control is of the parallel type with the following form:

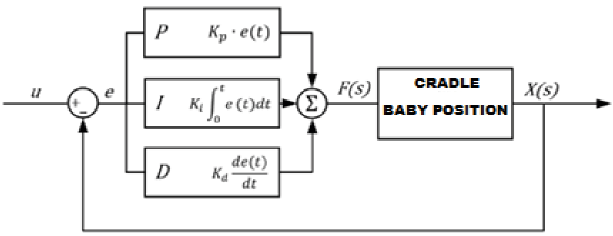

Figure 5. Parallel structure of the PID Control for cradle position control.

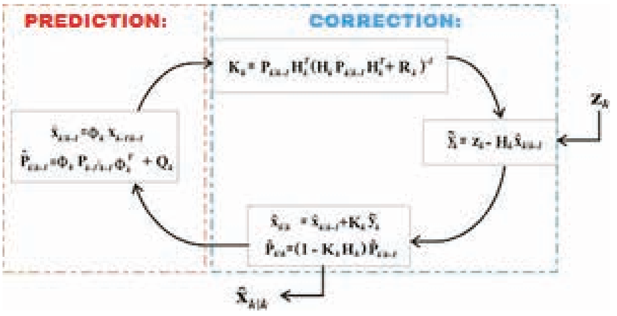

Figure 6. Structure of the digital Kalman filter to be implemented.

PID control consists of three elements, a proportional control action, where the control action is proportional to the error signal, which is the difference between the input and the feedback signal; the integral control action, where the control action is proportional to the integral of the error signal; and the derivative control action, where the control action is proportional to the derivative of the error signal [3].

Since the Raspberry Pi Pico microcontroller board is being used as the steering and decision-making element, the digital controller will change to the following representation:

$$U_k = K\left[e_k + \frac{T_m}{T_i}\sum_{i=0}^{k-1} e_i + \frac{T_d}{T_m}(e_k - e_{k-1})\right] \quad (1)$$

where e_k is the input to the controller (error signal), T_m is the sampling period, K is the proportional gain, T_i is the integral time and T_d is the derivative time [4].

-KALMAN FILTER

Our Kalman filter to be designed to improve the oscillatory movement of the cradle with the servomotors will have the standard digital predictor-corrector structure as shown in the following diagram.

RESULTS

In 1992, the American Academy of Pediatrics (AAP) after a review of the medical literature related to the ventral position and Sudden Infant Death Syndrome (SIDS) determined that healthy newborns should sleep in the back (dorsal decubitus) or side (side) position in order to drastically reduce the possibility of Sudden Infant Death Syndrome commonly referred to as "Crib Death".

Babies who sleep on their stomachs have a 1.7 to 12.9 times higher risk of dying from "crib death" compared to babies who sleep on their backs. Children who sleep on their sides have twice the risk of "crib death" and are more likely to turn onto their stomachs than those who sleep on their backs. When the child turns from the side position to the prone position, the risk of "crib death" can increase up to 45 times [1].

The present project consisted mainly in the design of a PID control to ensure that the position of the newborn baby is always face up and thus drastically reduce the possibility that "Crib Death" can occur due to obstruction of its respiratory tract.

Depending on the movement of the baby placed in a cradle, its position will be permanently monitored by an accelerometer. If the baby were to move in such a way that it would occupy a position that would risk obstructing its airway such as moving sideways or face down, the servomotors would immediately move in the opposite direction of the baby's movement in such a way that they would lift the cradle at a sufficient angle to return the baby to a safe face up position.

To achieve this, it was necessary to develop a PID type control together with a Kalman filter for a better response of the servomotors. These algorithms were programmed on a Raspberry Pi Pico microcontroller board.

The following image shows the crib and a doll that were initially used for testing.

Figure 7. Initial testing crib.

The tests performed have allowed improving the design of the PID Control and the Kalman Filter so that the mechanism that controls the cradle works in a smoother and more precise way.

In the following graph Angle (Degrees) vs. Time (milliseconds), the response of the servomotors with the PID control already implemented is shown. Almost immediate response is observed, although there is an overshoot, the servo motor goes to the required angular position very quickly and thus the baby will quickly return to a safe sleeping position.

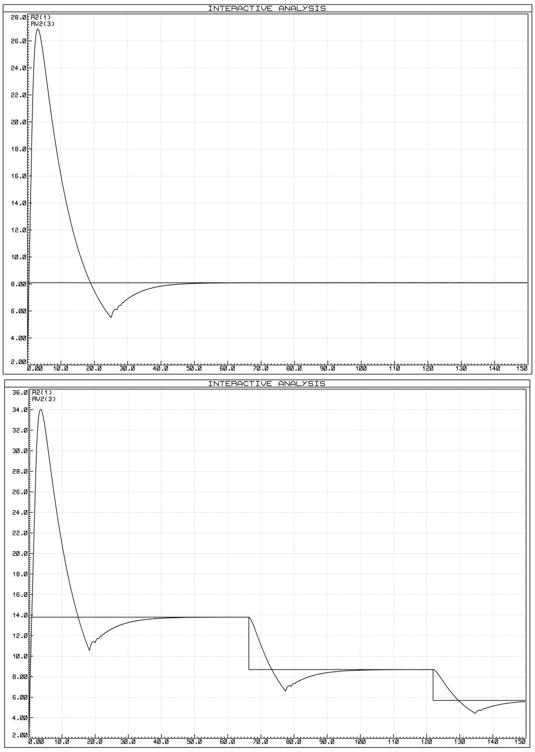

Figure 8. Servomotor response to angle changes required to return the baby to a safe position.

In discussions with medical personnel from the General Hospital of Tecamachalco, Puebla, Mexico; it was confirmed that crib death is highly dependent on the sleeping position of babies.

Based on the above, and on tests performed with newborn babies, we can say that the PID control together with the Kalman filter designed for this project meet the requirements to move the baby to the cradle quickly and efficiently so that the baby is not placed in a position that puts it at risk of obstructing its airway.

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