



MIMO Pillow - an Intelligent & Ergonomic System for Developing Physiological Parameters in New-born Infants

#1 Tejas A. Thaware,

*2 Akanksha T. Ware,

#3 Pradnya R. Sakhare,

*4 Rajashri R. Ramteke,

#5 Tejaswini A. Bankar

Final Year (Biomedical Engineering), Dr. Bhausaheb Nandurkar College of Engineering and
Technology, Yavatmal, Maharashtra, India.

Abstract-

Premature infants are subjected to numerous interventions ranging from a simple diaper change to surgery while residing in Neonatal Intensive Care Units (NICUs). These neonates often suffer from pain, distress and discomfort during the first weeks of their lives. Pharmacological pain treatment cannot be considered as a source to relieve a neonate from pain or discomfort. A non-pharmacological solution, MIMO has been designed to mediate the parent's heartbeat by means of vibrations, much like a pulse sensed by the photo plethysmograph sensor. The MIMO concept consists of two parts: a recording unit and a technologically enhanced pillow. The recording unit is used to record physiological data (such as heartbeat, breathing rhythm, parental smell and body temperature) from a parent which can then be transferred to the pillow, which includes technology to enable it to 'replay' the recorded data to the neonate. The main controller of the MIMO Recorder is an Arduino Uno microcomputer, which handles almost the complete recording process ranging from sensing the heart-beat vibrations and storage to transmission of the heartbeat to the Pillow. The MIMO aims at comforting a neonate by providing the baby with a feeling similar to that of being close to a parent to relieve pain.

I. INTRODUCTION

Babies born during 37 weeks of gestation are considered as premature babies. Being premature, their physiological systems are under-developed. They face various physiological problems.

Several techniques like the non-nutritive sucking; facilitated tucking and kangaroo mother care are used nowadays for reduction of the discomfort of the infant. The Kangaroo Mother Care (KMC) is the most effective method for the reduction of the pain of the infants. Apart from the skin to skin contact and maternal scent, one of the features of KMC is the exposure to the maternal heartbeat. The same holds for nurses, as they often have multiple neonates to care for. A comforting solution that does not require the continued presence of a parent or nurse is thus a design path worth exploring. So the concept called MIMO has been introduced to provide the comfort and to reduce the discomfort during painful interventions. This study introduces a new concept of comforting the preterm neonates by generating the selected features of the mother

and making her features available to the neonates when their mothers are not present. The goal of this project is to improve the wellbeing for the pregnant woman and her child before, during and after delivery. The parents have to just record their physical parameters and provide them to the infants. A User Centered Design (UCD) is applied during the industrial design process and based on the outcome of user research defines system requirements and make decision on technological directions. In UCD the end-user is constantly involved in the design process. In this case, medical staff and parents can be valuable sources of information, in effect becoming the voice of the neonates.

II. LITERATURE REVIEW

Premature new-born infants are admitted to the Neonatal Intensive Care Unit (NICU) for various observations by the neonatologists and the concerning medical staff. These babies have to be reliant on various interventions like removal of



sensors, intubations, detubations etc. which might prove painful and stressful to them. Some of the procedures environmental factors are also responsible for the pain and discomfort of the neonates. The various systems in the babies like the nociceptional system, does not fully develop due to their premature birth. The stimuli such as light or sound are not painful to the normal human beings. But such stimuli prove very painful to the premature babies. Also the clinical procedures performed on them increase their sensitivity to the pain. The exposure of the infants to the repetitive pain inside the incubator affects negatively on their nervous systems. These negative effects of the untreated procedures are for severe and long term. There are many techniques for the reduction of pain and discomfort. The neonates show various signs of discomfort. These signs can be both physiological and behavioural. The behavioural changes include crying and whimpering, facial expressions like grimacing with eyes squeezed shut or a stretched open mouth, and body movements like finger and toe splaying and trunk arching. The physiological signs include an increased heart and respiratory rate, increased or decreased blood pressure, decreased oxygen saturation, vagal tone and skin temperature.

III. TECHNIQUES FOR REDUCING THE DISCOMFORT

Some of the solutions have been invented for reduction of the discomfort of the infants. The most popular techniques for the reduction of the discomfort are:-

A. Non-nutritive Sucking:

Non-nutritive Sucking is the method in which the baby is given a sweet solution to suck. It acts as a dummy for the breast feeding. A sucrose solution is given to the baby to suck on with the help of pacifiers. This reduces the pain experienced by the infants while performing the painful procedures. This technique helps to enhance the sucking and the weight gain of the baby. It also helps to improve the breathing of the premature baby and also calms the baby.



Fig 1:- Non-nutritive Sucking

The repetitive sucking causes the malocclusion in mixed dentition. This is the condition where the teeth are improperly aligned in later childhood during the age of 6 to 13 years.

B. Facilitated Tucking:

In the facilitated tucking the caregiver keeps one hand on the baby's head and other anywhere on the body. The baby is kept on one side and accordingly the baby is held by the caregiver. This is more effective method than the non-nutritive sucking as the sucrose has to be administered 4 times a day only. The gentle care of the caregiver is provided in this technique. This gentle care has a great effect on the baby.

The baby has to be taken out of the incubator for providing this care. If the baby is taken out of the incubator, then the physiological parameters like temperature and humidity maintenance would be affected.



Fig 2:- Facilitated Tucking

C. Skin-to-Skin Care:

One of the most successful comforting techniques is skin-to-skin care (SSC), otherwise known as Kangaroo Mother Care (KMC). During SSC the mother and infant are wrapped in cloth together, with the infant held to the bare chest of the mother. This is a very pleasant experience for the infants for reducing their pain and discomfort.



Fig 3:- Kangaroo Mother Care

One downside of this comforting technique is that the neonate needs to be taken out of the incubator for 23 hours for the provision of KMC, which can be stressful to the child. Some neonates are unable to receive this particular kind of care, because their medical condition does not allow them to be taken out of the incubator. This paper is based on the concept of Kangaroo Mother Care (KMC) for the providing the replica of parental parameters to the baby.

IV. DESIGN CONCEPT

One of the parameters used in KMC is maternal heart-beat. From the literature review, this comforting solution for premature infants has been proposed. Neonates show less stress sign when their parents hold their babies firmly to their chest. This is a very pleasant experience experienced by the neonates. This comforting solution called MIMO is designed in such a way that the baby feels the presence of its parent. The designing of the device aims at providing the Kangaroo Mother Care inside the incubator itself being physically the parents absent and providing the similar feeling of the parent's parameters to the neonate. Another feature of this device is that, the parents can record their data without any professional guidance.

This concept might not only increase the general comfort level, but it can also contribute to the bonding between parent and infant. MIMO gives parents the chance to record their personal features such as heartbeat, smell and temperature, which can be mediated to the child when it is in need of comfort. When the concept is fully realized, the child might experience a feeling as the parents are close to them, even when the parents are not physically there. This creates a strong bonding between the parent and the child and makes him comfortable. One of MIMO's basic characteristics is its ease of use, which enables parents to record

their physiological features without guidance of any concerning professional.

The prototype is defined in such a way that, the parent himself or herself records his or her heartbeats so that the nurse or concerning medical staff should just switch-on the button. These heartbeats are then conveyed to the pillow. The pillow works on itself, thus helps to reduce the on the power supply inside the incubator. It also helps to replace the use regular pillow avoiding extra load in the incubator. The prototype is provides comfort to the neonate in an ergonomic way and the pillow used is washable according to the hospital standards. The prototype consists of two parts:-

1. A recording unit (MIMO recorder): It is used to record the heartbeats of the mother.
2. Pillow (MIMO pillow): It is used for transmitting the heartbeats to the neonate.

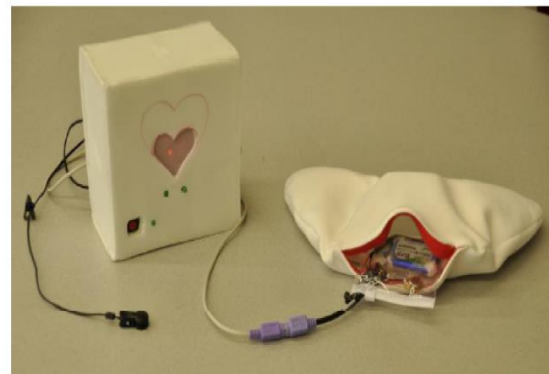


Fig 4:- Prototype with the MIMO Recorder (left) and the MIMO Pillow (right).

A. MIMO Recorder:

The recorder is a cubical box which is used to record the heartbeats of the mother. It consists of a photoplethysmograph sensor, amplifier, band-pass filter and Arduino Uno. It also consists of a transmission line which would be used for the transmission of the heartbeats. It has displays like LEDs as indicator for recording process and transmission. The block diagram of the recorder is shown in fig(5).

A. MIMO Pillow:

The pillow is that part of the device which will always be with the neonate. It is boomerang-shaped that is designed with respect to the design of the



'Fredrick T. Frog' by Philips. It has stability and a soft cushioning effect having polymer beads that help to surround the baby. The materials are chosen according to the suitability of the NICU environment.

The block diagram of the pillow circuit is given fig(6). It consists of a reception line which will receive the recorded signal from the recorder and store it in Arduino Mini. The Arduino Mini acts as a minicomputer and supplied by power supply to work separately.

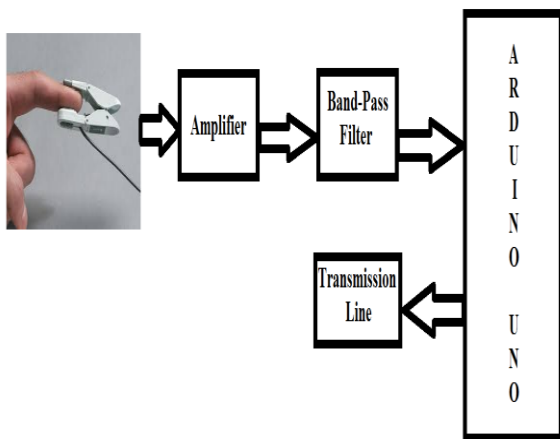


Fig. 5:- Block diagram of Recorder.

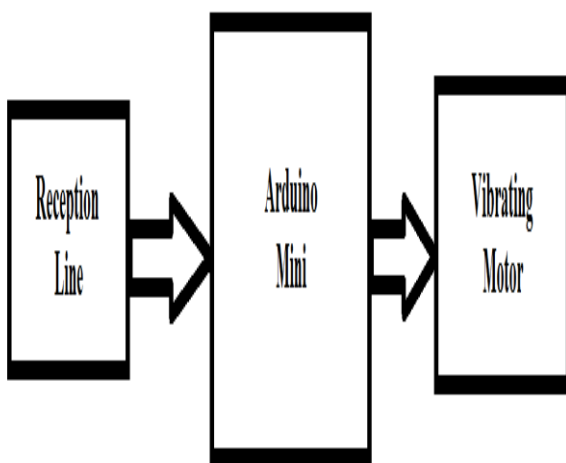


Fig 6:-Block Diagram of the circuitry in the pillow.

The Arduino Mini is too flat to be felt outside the pillow. It is same as the Arduino Uno in the recorder. A tiny vibrating motor is connected to give the vibrations according to the heart rate.

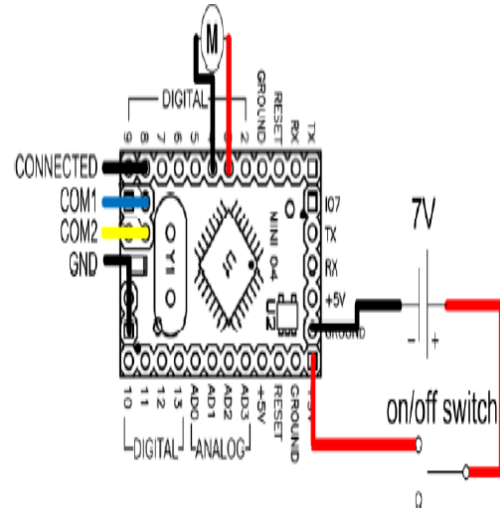


Fig 7:- Circuit Diagram of MIMO Pillow.

The above figure shows the circuit diagram of the pillow circuit. Its main controller is Arduino Mini. It is another version of the Arduino which is specialized flat model. Due to its flat structure, it is hardly felt from outside and the infant is easily comfortable. The ergonomics of the pillow is in such a way that the electronics is not felt from outside. The circuit part consists of racing battery and a tiny vibrating motor also. This motor vibrates according to the pulsed signals received from the Arduino Mini. The pillow vibrates according to the vibrations of the motor.

V. USER INTERFACE AND METHODOLOGY

A. Recording the Heartbeats:

The mother has to be kept in relaxed position. The photoplethysmograph sensor is connected to the mother's fingertip or earlobe. The mother has to record her heartbeats in the recorder with the help of this sensor. The recording starts when the recording button is pressed after attaching the sensor to the finger. The recording LEDs blink for showing that the recording of the heartbeats is under process. These LEDs stop blinking and glow continuously showing the completion of the recording of the heartbeats. The mother can now remove her finger, safely, after the recording.



Fig 8:- A mother recording her heart beat using the MIMO recorder.

B. Transmission of Heartbeats:

To transmit the recorded signal the transmission line in the recorder and the reception line in the pillow are connected. For the transmission, the switch for transmitting the data is pressed. The completion of the transmission is shown by the blink of other LEDs in the recorder. The reception and transmission lines could be now be removed. The pillow circuit has its own power supply to work individually. According to the digital signal received by recorder, the vibrating motor vibrates the pillow.



Fig 9:- A baby with the MIMO pillow.

VI. ADVANTAGES

1. The device seems to be a simple, effective and safe intervention for pain in newborn infants.
2. This device is portable and very easy to use.
3. The parents can record the heartbeats on their own without any technical guidance.
4. The infants do not show any signs of pain when the pillow is kept on their chest.
5. It reduces the crying time of the baby while performing the medical procedures.
6. Due to this gentle care, this enhances the physiological parameters of the infant and so does improve them.

VII. CONCLUSION

1. This paper presents the concept of providing the same feeling as that of the baby's mother.
2. This device helps to strengthen the bond between the child and the parent.
3. It gives a non-pharmacological solution to reduce the pain and develop other parameters of the baby. It gives an intelligent device with a recorder to record the heartbeats and the pillow gets vibrated according to the maternal pulsations.
4. The Kangaroo Mother Care can be provided to the infant inside the incubator itself.
5. The precautions of the pillow are easily checked by the mother and then it is provided to the infant.
6. This also adds to the safety of the baby with this incubator.

VIII. FUTURE WORK

1. The future work consists of recording other parameters of the parents (body temperature, body smell etc.) and studying the effect of them on the baby by transferring to the pillow.
2. A wired connection is used for transmitting the heartbeats from recorder to the pillow.
3. This device could be improved for the transmission of data by wireless technologies like Bluetooth.



4. In this device, Arduino Uno was used for recording the heartbeats and Arduino Mini was used for storage of the heartbeats.
5. Instead of using two Arduino, we can design this device using a single Arduino.
6. This can reduce the bulk of the device and also the cost of it.

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