Internet of Things based Feedback Control System for Pediatric Pain Assessment and Management

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Abstract—A child's laughter radiates happiness in the most natural and innocent way. However, unlike just smiling to express joy, until at least six years of age children find it very challenging to comprehend and narrate the characteristics of their pain (its nature, location, and type). Thus, it is essential for parents, health care providers and nurses to identify this pain via the child's behavior like facial expressions or cry pattern, and provide these tiny bundles of joy with adequate comfort. Motivated to support these little ones during these moments while providing automated assistance to nurses and even parents, we decided to explore the applications and role of Internet of Things (IoT) in the monitoring, assessment, and management of pediatric pain, and propose an IoT-based feedback control system that can assess a child's pain level by analysing their facial expressions and cry pattern, and help reduce it by distracting the child with music or videos as well as alerting the parents and doctors.

Index Terms—Pediatric pain, facial expressions, feedback control system, internet of things, cry pattern, distraction

I. Introduction

Since its recognition, Internet of Things (IoT) has shown staggering advancements and various breakthroughs that have led to its inclusion in areas like healthcare, agriculture and even one's day-to-day lives. However, as per our knowledge, IoT has not yet significantly contributed to the field of pediatric pain. In fact, in a recently published article, Argüello Prada concluded *"Although there are examples of the use of IoT in pain assessment and management, the field is still in its infancy."* [1]. Therefore, we began our research with an objective to design a robust, effective, and efficient IoT based solution that can assist various care providers to deal with pediatric pain.

It was not until after the 1970s or 1980s that it was realized that just like adults, babies too feel pain [2]. Following this insight, babies began receiving proper anesthesia during painful medical procedures across the globe. Moreover, research shows that negligence of pain in children can have serious long-term effects such as chronic pain or fear of hospitals or needles that prevents these kids from receiving proper medical care when needed [2].

Given their inability to communicate verbally, babies have their own sign language that they use to express numerous emotions, even that of pain. A child's pain can thus be detected in two ways, either using a pain assessment scale that is based primarily on child's facial expressions [3] (eg. The Faces Pain Scale proposed by Hicks et al. [4]) and other factors like vital signs and limb movement, or the baby's cry pattern(as done by Tejaswini et al. [5]). Meanwhile, some of the solutions that are currently in use to reduce baby's pain mainly during and after a medical procedure like surgery or even vaccination include topical analgesics, oral drugs, and even non-medicinal ways like distraction (such as bubbles, video games, virtual reality), caressing, maternal skin-to-skin contact, and sugar water [2]. As per our literature survey, IoT has relatively been used more in the assessment of pediatric pain [3], [5] but before further looking specifically into the integration of IoT and pediatric pain care, we had to find out how technology in general has contributed to the field of pediatric pain.

Finley et al. [2] provided a great account on the incorporation of technology in pediatric pain management. They discussed the chief goals of application of technology in pediatric pain management such as easier access to pain treatment, decreases in costs, higher effectiveness, and lesser human intervention. Their study also suggested various ways in which technology can help maintain those squeaky cute giggles. Examples include videoconferencing, private computer network, personal digital assistants, and virtual reality. However, Internet of Things was not explicitly mentioned in the paper, so we then recognized the major contributions of this study based on the papers that were published under the category of the state of the art for IoT in pediatric pain.

A. Major Contributions

The major contributions of this study are as follows:

- Design an IoT-based feedback control system that involves least human intervention possible. As stated by [1], most IoT-based solutions applied to pain management use the individual's viewpoint about level of their pain and its description. The model proposed in this study aims to use facial expressions, cry patterns and vital signs of the babies less than or equal to 1 year old to automatically predict severity of pain they are feeling, and provide feedback accordingly.
- As per our knowledge, IoT has not gained as much recognition in the field of pediatric pain as it has in other domains of healthcare like remote patient monitoring and

control of spread of viruses [1], [6]. This study proposes an automated IoT-based solution targeted to pediatric pain assessment and management.

II. Literature Survey

Using keywords like "pediatric pain" and "pain" in conjunction with "Internet of Things", we were able to retrieve a total of 481 publications. These included 67 results from Institute of Electrical and Electronics Engineers (IEEE) of which two focused on pediatric pain assessment using IoT framework and two were related to pediatric care, 258 articles were from Association for Computing Machinery (ACM) of which 11 were related to pediatric pain care and management but discussed the application of other technologies such as virtual reality, interactive storyboards, and robots to help children experiencing acute and chronic pain, and 156 results were from Elsevier of which none focused on pediatric pain.

Tejaswini et al. [5] developed a cloud-based framework for babies in the Neonatal intensive care unit (NICU) that distinguished an infant's cry pattern to deduce whether the baby was in a state of pain, discomfort, or hunger. The cries were categorized by Support vector machine (SVM) based neural network, forwarded to Thingspeak (an IoT data visualisation and analysis platform) and the results were displayed on the end user's mobile phone.

Zhong and Liu [3] presented an IoT-based Remote Neonatal Pain Assessment System that entailed a network connecting all incubators in the NICU. The system automatically captured video of facial expressions of each infant and forwarded it to the remote pain assessment center where professionals derived the corresponding pain intensity. Pain levels given by various professionals were then recorded, processed and saved to gradually reduce human intervention in pediatric pain assessment.

Aiming to mitigate neonatal pain during medical procedures by at least 50%, Hauser et al. [7] proposed Calmer, a device that mimics maternal skin-to-skin contact for prematurely born infants in the NICU. Calmer simulated the mother's heart rate and breathing motion for each respective infant. It was controlled manually via a GUI displayed on a laptop and using an Arduino microcontroller. Even though this is not an IoT based system, it made us wonder what would be the most commonly used approach used to reduce a child's pain and that can be modelled by an IoT framework . And after reviewing Srouji et al.'s paper [8], our conclusion was distraction!

Distraction, as previously stated is one of the myriads of ways in which a child can be comforted during moments of pain. This technique can be adopted by parents, doctors and even child life specialists during painful medical procedures including immunizations [8]. Methods of distraction can be classified in two types - passive distraction and active distraction [8]. Passive distraction involves only the care provider making an effort to gain the baby's attention such as by playing music or singing a song. On the other hand, active distraction encourages the child's participation in activities like playing games or spending time with a pet [8]. Our goal is to focus on the use of passive distraction to reduce a child's pain via our IoT-based model.

III. Research Proposal

Bringing the above findings together, we formulated our end goal. We aim to design and implement an IoT-based feedback control system that gauges how much pain a baby less than or equal to one year old is feeling and provides feedback accordingly. The state of pain and its intensity will be determined by analyzing the child's facial expression and cry pattern along with vital signs. Feedback will then be provided based on the level of the pain level, and will include measures like playing music, turning on a video, and/or even alerting the parents and doctors.
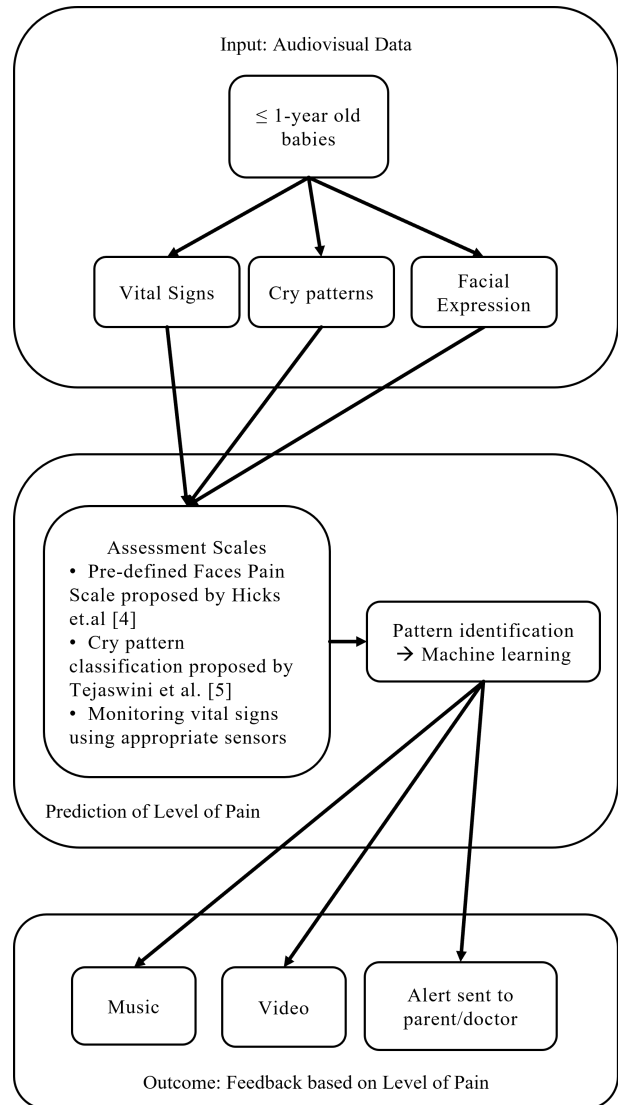

Fig. 1. Block diagram illustrating feedback control system for pediatric pain assessment and management

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