Non-Contact Vital Sign Monitor for the NICU

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BACKGROUND

Conventional vital sign monitors use mechanical or adhesive sensors that physically contact the patient's skin. They are susceptible to artifacts and false alarms caused by patient movement and sensor dislodgment. Unfortunately, with infants in the NICU, the extremely fragile nature of the premature infant's skin greatly increases these incidents.

Recent technology in visual analytics allows for detection of vital signs such as heart rate, respiratory rate, and temperature by using a camera without contact with the patient. Combining these data with environmental factors may reduce the rate of false alarms common in conventional vital sign monitoring systems in the NICU. Additional benefits include potentially improving the infant patient experience by reducing the number of physical connections, reducing the incidence of skin infection in premature infants caused by conventional sensor leads, and enhancing the level of patient care by correlating environmental and contextual information with changes in vital signs.

A camera-based vital monitoring system can supplement existing NICU monitoring as a post-analysis tool or replace existing sensors in the NICU and additional clinical settings, such as the intensive care unit (ICU) and emergency room (ER), where unreliable monitoring can delay critical treatment decisions. Future versions may be developed for regulated in-home monitoring and transformative telemedicine applications such as remote monitoring of acute respiratory disorders that can be remotely monitored after the patient leaves the hospital.

OBJECTIVES

Our technology aims to deliver non-contact monitoring to determine vital signs including respiratory rate, heart rate, and skin temperature without attaching sensors to the infant's skin. The study is being conducted at Lucile Packard Children's Hospital Stanford to test, validate, and further the development of an innovative technology to improve vital sign monitoring in the NICU.

The goal is to design a system that can detect sudden infant patient physiological changes and distinguish between relevant data and false alarms or waveform artifacts caused by patient motion, position, or the unreliability of the sensor-to-skin interface.

The objectives of the study are as follows:
a) design camera prototypes to record videos within the NICU environment,
b) build standard sensor datasets with camera video along with EMR data, and
c) validate existing algorithms and further develop post-analysis software.

METHODS

We collected data comprised of continuous 48-hour video recordings each from 15 infants at 1280x720 resolution and 30 frames per second (FPS), placing the camera approximately 4-6 feet from the bassinet (Fig 1). Simultaneously, vital sign data were recorded from contact-based sensors through Lucile Packard's Research Data Export system used to monitor vital signs, with no change to the patient's standard of care.

Phase 1 of the study focused on non-contact measurement of infant breathing. We used Tensorflow to re-train inception models to use the data to identify the presence of an infant in the frame. Pixel motion in thoracic and abdominal regions were quantified using motion histograms and optical flow gradients.

Phase 2 of the study will involve evaluation of heart rate sensing with cameras using photoplethysmography (PPG) and temperature sensing using thermal sensors.

Fig 1. Left: Camera setup next to the NICU bed. Right: Example of the recording frame.

RESULTS

We obtained **84% accuracy in identifying the presence of the infant** in the bassinet using a dataset of 1,000 images. Upon analyzing the breathing signals, we observed a **clear separation of breathing signal energy** when there was an infant present in the bassinet compared to when the infant was absent from the bassinet (Fig 2).

With 30 selected videos (300 minutes total duration) where infants were tightly swaddled in multi-color blankets, we were able to extract a continuous breathing signal with a **maximum variance of 5 breaths per minute** (bpm) in comparison with recorded data from standard of care equipment. Fig 3 shows a one minute signal from this dataset.

RESULTS contd.

Challenges to collecting high quality breathing motion signals were markedly evident under the following conditions: thick, all-white blankets, loosely wrapped blankets, motion artifacts due to body movements, nurse visits, and signal noise introduced due to poor low-light performance of cameras.

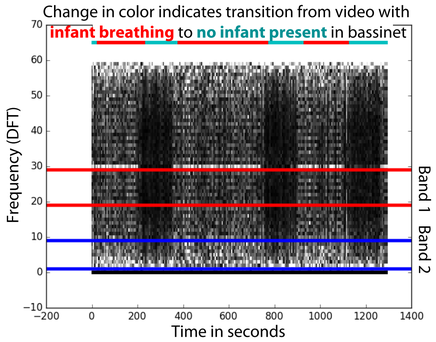

Fig 2. Clear Separation of Respiratory Breathing Signal Energy Obtained from Visual Analytics

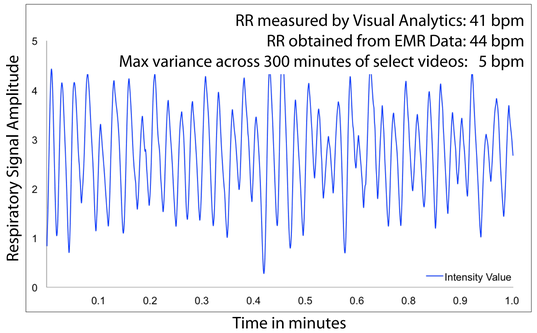

Fig 3. Respiratory Pattern Extracted from Video

CONCLUSION

Camera-based vital sign monitoring is a promising technique as an apnea monitor in the NICU environment. Further work will continue to evaluate the ability to record sudden physiological changes in comparison with current standards.

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