Automated Neonatal Vital Sign Extraction Using OCR in Kenya: A Feasibility Study

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Introduction

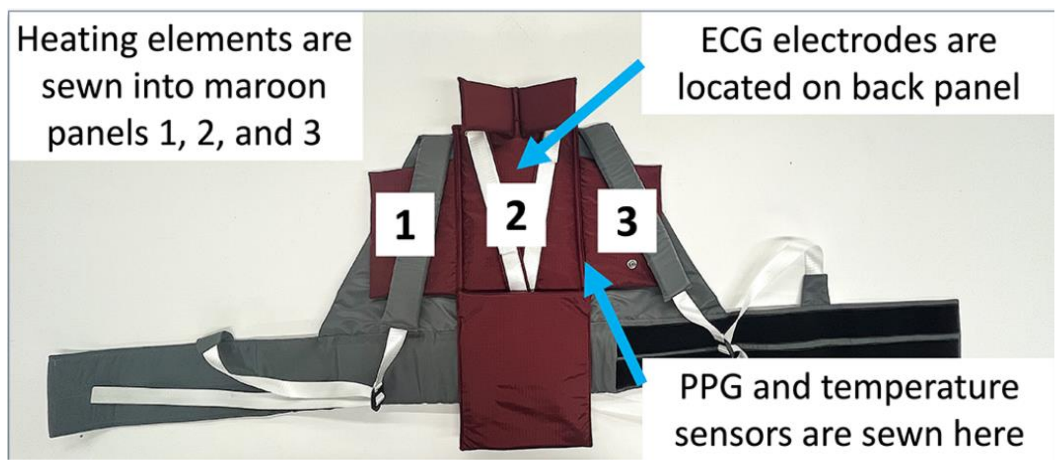
- ❖ Globally, over 13.4 million premature births occur annually, and premature birth increases the risk for neonatal mortality
- ❖ Mortality risk is particularly acute in low-resource settings characterized by staffing constraints and insufficient medical infrastructure.
- ❖ We present an integrated solution to address this challenge in low/middle-income countries (LMICs):
- ❖ NeoWarm: Patented* textile-based, low-power wearable carrier for vital sign monitoring.[1,2]
- ❖ NeoRoo: Offline-ready mobile app for clinical decision support.[3]
- ❖ NeoSmartML: Edge-AI tool for automated risk prediction from NICU monitor images.

Methods: System Evaluation

Prior validation:

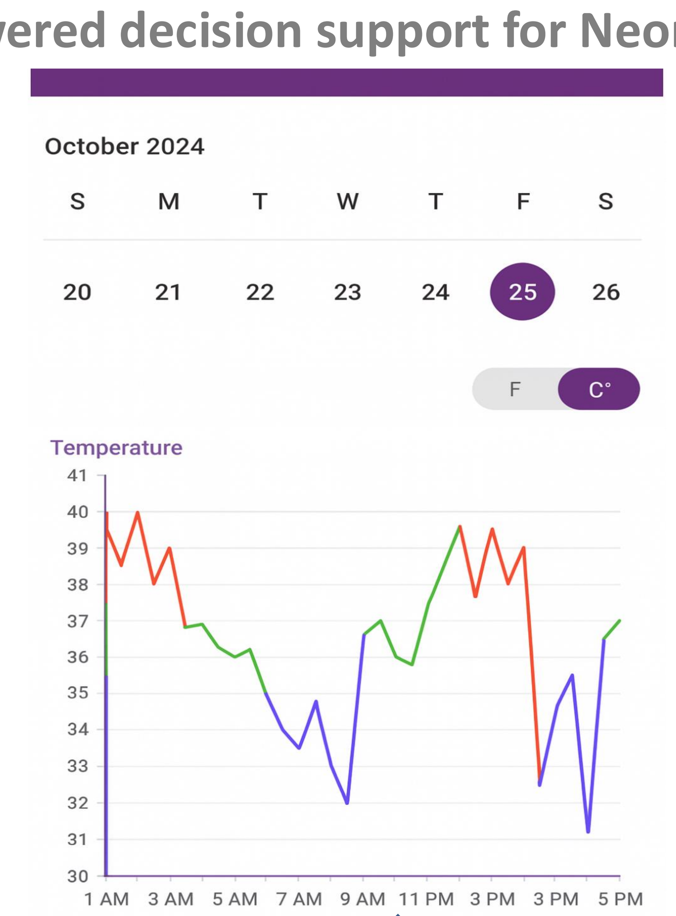
- ❖ SpO_2, HR, ECG, temperature sensors benchmarked; BLE validated in RF chambers; OCR tested on 10k screenshots; ML via k-fold cross-validation; inference on Android 8-13; security via penetration testing.
- ❖ 4-day study (April 23-26, 2025) at Mama Lucy Kibaki Hospital, Nairobi, Kenya
- ❖ Three ESP32-CAM modules captured vital sign displays at 5-second intervals with WiFi synchronization to Raspberry Pi
- ❖ Deployment: NICU (2 cameras, 52 hrs), NBU (1 camera, 3 hrs)
- ❖ Nurses provided risk classifications (High/Normal/Low) every 30 minutes
- ❖ Vital signs: Heart Rate, SpO_2, Respiratory Rate

Methods: System Design & Development



An Integrated System for Neonatal Monitoring

Wearable sensing and AI-powered decision support for Neonatal Care



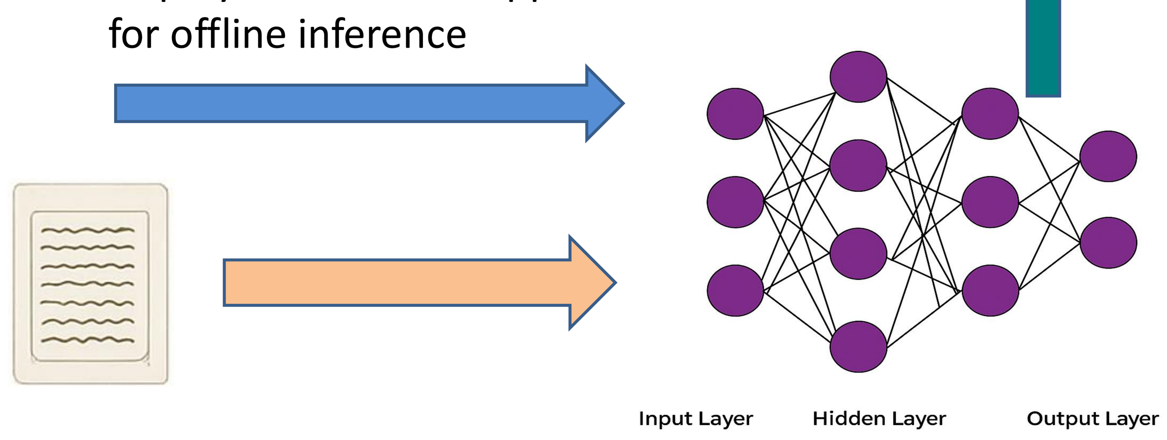
NeoWarm Device

- nRF52840 Bluetooth 5.4 SoC
- Sensor array: MAX30102 (SpO2, Heart Rate), MLX90614 (Temperature), AD8232 (ECG)
- AES Encryption peripheral for data security

NeoRoo App

- Dual interface for parents, caregivers
- Concurrent connections with up to 20 NeoWarm devices with 60 FPS update rate
- Encryption during storage and RF transmission
- Adaptive connection, re-connection rates; compression data transmission.
- Quick sync with DHIS2 through delta synchronization and compression during upload

Deployed on mobile application for offline inference



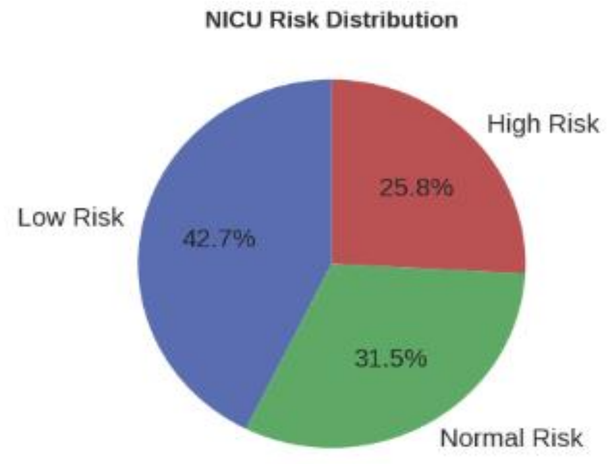
NeoSmartML

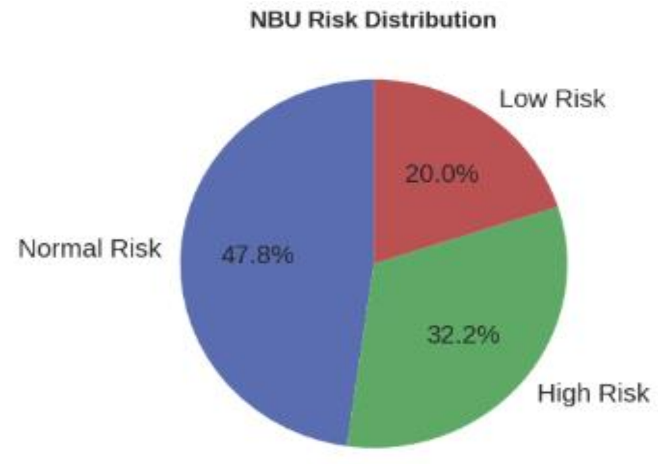
- ESP32-CAM to capture images.
- Pre-processing + EasyOCR for extracting vital signs by first isolating labels; accuracy tested over public datasets.

Neural Network Architectures

- Streaming Multimodal Transformer (SMT)
- Streaming Cross-modal Transformer (SCT)
- Feature Fusion Module

Results





Metric or finding	NICU (2 cams)	NBU (1 cam)
Monitoring Duration	52 hrs.	(camera displaced)
Nurse Annotations	178/208 (86%)	90/102 (89%)
OCR Success Rate	62,8%	91,6%
Risk Level Change	Every ~2,5 hrs.	Every ~4 hrs.

Statistical Findings

- Significant differences in risk classification dynamics between NICU and NBU (χ^2=13.96, p<0.001), small effect size (Cramer's V=0.23)
- Statistically significant differences in vital sign distributions (HR, SpO_2, RR; all p<0.01), small effect sizes (Cohen's d<0.3)
- NICU: 1 risk level change every ~2.5 hours (higher acuity patients)
- NBU: 1 risk level change every ~4 hours (more stable patients)

Clinical Integration & Data Quality

- Sustained nurse compliance >85% demonstrates successful workflow integration
- NICU: 74,880 OCR capture attempts over 52 hours
- NBU: 2,160 OCR capture attempts over 3 hours
- Both units: High annotation response rates (86-89%) indicate clinical acceptance
- Camera displacement in NBU reduced monitoring duration but maintained data quality
- Risk classification changes aligned with documented clinical events, confirming annotation validity

Performance Analysis

- Temperature data not captured (digital displays absent in both units)
- NICU challenges: Multiple overlapping displays, variable lighting, complex monitors
- NBU advantages: Simpler layouts, controlled lighting, optimal positioning
- Missing data more frequent in NICU due to environmental variability

Conclusions & Future Directions

- ❖ Automated neonatal vital sign capture with NeoVitals demonstrated technical feasibility, achieving OCR accuracy of 62.8-91.6% and sustained nurse compliance (>85%)
- ❖ Despite challenges with camera displacement, lighting variability, and heterogeneous monitor formats, overall feasibility was confirmed
- ❖ Findings provide foundational evidence for neonatal risk stratification model development
- ❖ This study illustrates the potential of NeoVitals to scale beyond a single site, enabling multi-site data collection across diverse clinical environments
- ❖ Critical for developing a robust neonatal foundation model in resource-limited settings

Future directions:

- ❖ Expanding the OCR dataset; optimizing for diverse monitor formats; enhancing algorithms for challenging lighting conditions; conducting real-world clinical validation across additional hospitals in Kenya and beyond

References

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