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Maternal Health Transformation: Harnessing IoMT for Advanced Risk Assessment and Monitoring

[1]Dipali Panchal, [2]Dr. Krunal Vaghela

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Abstract. This research introduces a groundbreaking approach to enhance maternal health in remote developing regions through IoT-enabled wearable sensing technology. Despite persistent challenges in reducing maternal and fetal mortality rates, the integration of intelligent machine learning algorithms into healthcare systems presents significant promise. The proposed system not only monitors maternal well-being but also delivers real-time health updates to both mothers and their families.

Emphasizing the critical aspect of accuracy in technological solutions, particularly in remote developing regions, this research highlights the potential transformative impact of IoT-driven wearables on maternal and infant healthcare. The study aims to contribute valuable insights to the ongoing global efforts focused on reducing maternal and fetal mortality rates through innovative and effective technological interventions.

Keywords: *Revolutionizing Maternal Healthcare with IoT, Wearable Sensors, and Artificial Intelligence.*

1. Introduction

In low- and middle-income countries, preventable complications during pregnancy contribute significantly to maternal mortality rates. A lack of awareness about risk factors further hinders effective prevention. Accessing pregnancy-related care is challenging and expensive, mainly due to limited availability of devices in health complexes.[9] Complications during pregnancy and childbirth are major contributors to preventable deaths, especially in resource-limited countries, where lack of knowledge remains a critical issue. Concerns related to neonatal well-being, such as underdeveloped fetal growth and infections during childbirth, add complexity[11]. Timely identification and communication with healthcare providers are crucial for effective intervention, but accessing medical aid in rural regions remains a challenge.

This paper proposes a remote healthcare system for maternal health in non-urban developing countries. Utilizing IoT-based medical sensors, the system collects and analyzes patient data, predicting maternal health status. The information is then remotely transmitted to medical experts for timely intervention. To address data and computational challenges, diverse computing frameworks, including edge, fog, and cloud platforms, facilitate efficient data storage, processing, and classification. The process involves sensor data collection, fog layer optimization, algorithmic analysis, and cloud-based data storage for refined decision-making.

In summary, this proposed remote healthcare system aims to overcome challenges in maternal and infant healthcare by leveraging IoT technology and diverse computing frameworks, ensuring timely and effective interventions in non-urban developing regions.

Department of Computer Engineering, Marwadi University, Rajkot, Gujarat 360003, India
Email: Dipali.panchal@marwadieducation.edu.in
Email: krunal.vaghela@marwadieducation.edu.in

2. Literature Review

Vyacheslav Shulgin[6] Premature or preterm birth is a significant cause of long-term morbidity and a primary contributor to neonatal fatalities. The existing devices and methods for monitoring and predicting preterm births are known for their inaccuracy, invasiveness, high cost, and limited applicability to hospital or clinical settings. A promising avenue for improvement involves analyzing Electrohysterography signals (EHG) obtained from the abdominal region of pregnant women. These signals have shown effectiveness in predicting preterm births.

A particularly crucial component of these signals is the Conduction Velocity (CV) observed during uterine contractions. This paper introduces an algorithm designed to estimate CV through the space-time processing of abdominal signals. Developed based on actual EHG recordings, this algorithm aims to provide a more accurate and non-invasive method for estimating CV, thus enhancing the prediction of preterm births.

YunusSantur[7], Contemporary society heavily relies on the internet for a myriad of purposes, ranging from information gathering to socializing with friends and family, as well as handling official business. The prevalence of virtual social networks has become increasingly prominent, complementing traditional offline networks. Facebook, as the largest global social network, exemplifies the vast interconnectivity of people and companies.

Considering this, envisioning the creation of a dedicated social network catering specifically to pregnant women

emerges as a valuable concept. This platform could facilitate connections between expectant mothers, offering a space to share insights and experiences related to pregnancy. Within this virtual network, discussions could cover various aspects of a baby's development, dietary recommendations, potential risks to monitor, reliable sources of information or assistance, optimal timing for regular scans, vaccination schedules, and key indicators like weight and height at different stages of a baby's growth.

Establishing such a network would contribute significantly to raising awareness about pregnancy-related risks and promoting the well-being of both mothers and babies. By fostering a supportive community where individuals can exchange valuable information and experiences, this virtual platform has the potential to empower pregnant women with the knowledge needed to navigate their pregnancy journey successfully.

LingyunWu[8] Ultrasound (US) images play a crucial role in monitoring the fetal growth during a pregnant woman's gestational period. These images provide essential information such as the baby's size, weight, and heart rate, serving as indicators of the overall health of the baby. Additionally, they serve as a means to detect potential abnormalities, including missing or double organs and deformities, enabling early decisions on whether to continue with the pregnancy or consider other options.

However, the current process of obtaining high-quality ultrasound images is labor-intensive and largely manual, primarily restricted to hospital or clinical settings. Recognizing the need to enhance image quality, reduce measurement errors, and improve both slice choice and accuracy, a novel method has been proposed to assess ultrasound image quality. This method leverages Artificial Neural Networks (ANNs), with two custom deep learning models known as L-CNN and C-CNN.

The L-CNN model is designed to identify the Region Of Interest (ROI), which is subsequently utilized by the C-CNN model to evaluate image quality and assess specific details of the body parts requiring measurement. To enhance model performance, the neural network is complemented with local features derived from the original data. The incorporation of multiple input sources is demonstrated to improve image quality.

Importantly, this method has undergone evaluation by a group of medical professionals, with results indicating its efficacy comparable to assessments made by actual doctors. This innovative approach holds promise for automating and enhancing the ultrasound image quality assessment process, potentially revolutionizing the way healthcare professionals analyze fetal development during pregnancy.

Nandakishor D Valakunde[9], India faces a higher incidence of stillbirths and a greater maternal mortality rate compared to other developing nations. To promote a safe pregnancy for both the mother and the baby, it has been recommended that pregnant women undertake a minimum of four visits to their healthcare providers. Addressing the healthcare challenges, the Smart ASHA Pregnancy Monitoring System (SAPMS) has been devised to diminish maternal mortality incidents. This system facilitates healthcare providers in reaching pregnant women in remote or underprivileged regions globally, leveraging various mobile devices, especially smartphones, and internet connectivity. SAPMS aims to deliver efficient and effective healthcare to pregnant women, especially in areas with limited access to medical resources.

Raghav Hari Krishna V S[10] The leading cause of perinatal morbidity is preterm birth. Accurate prediction of preterm births necessitates the collection of various information, including the mother's height, weight, gravida (number of pregnancies), and para (number of deliveries). A predictive model has been developed, demonstrating a high accuracy rate of 89.99%. This promising model holds the potential to identify women at risk of preterm birth, enabling proactive interventions to improve maternal and neonatal outcomes.

3. Related Work

3.1 Assessment of Risk Factors During Pregnancy

The consideration of factors Age, weight, blood pressure, existing health conditions, heart rate, body temperature, and physical activity are all important factors to consider, medical professionals are able to predict potential medical risks for expectant mothers confidently. Table 1 provides a summary of these parameters, including their values, weights, and references. The initial analysis of these basic medical factors is crucial in determining the risk level and worst-case scenarios. To predict medical risks for pregnant women, medical experts possess the ability to thoroughly assess a multitude of factors, encompassing.Table 1 summarizes the parameters, including age, weight, blood pressure, pre-existing medical conditions, heart rate, body temperature, and levels of physical activity, along with their respective values, weights, and references.

A distinct illustration of the distinctive attributes and innovations of this review vis-à-vis analogous works is encapsulated in Table 1. Through this comparative analysis, a clear differentiation between the present article and preexisting relevant reviews becomes evident, elucidating the unique contributions it brings forth.

Our goal is to investigate in the field of maternal and infant healthcare, wearable sensing technologies and AI/ML strategies are being employed to improve health outcomes. In doing so, a panoramic vista of challenges and prospects on the horizon for subsequent endeavors within this domain will emerge, ushering in novel pathways for future advancements.

Table1. Below are the relevant medical parameters,Vital Signs,Associated Value and Weights that ared significant during pregnancy

Parameters &Vital Signs	Low	Mid	High
Body Temperature [2]	averages about98.7°F (37°C).	<98.7F (37 C)and>102F (38.8 C)	Temperatures of 102 F (38.8 C) or higher and below 95 F (>35 C) indicate hypothermia
Heart Beats[3]	The heartbeat rate is 75-80 beats per minute	The normal range for the human heartbeat is between 90 and 140 beats per minute	The heartbeat should be more than 70 and less than 140 beats per minute.
Blood Pressure (BP)[9]	Systolic 120-139 mm Hg,diastolic 80-89 mm Hg	Systolic 140-159 mm Hg,diastolic 90-99 mm Hg	The systolic blood pressure is 160 mm Hg or higher, the diastolic blood pressure is 100 mm Hg or higher
Age [9]	21-30	31-36	37-47
Fetal Movement[5]	In the span of 12 hours,12 movements which may include kicks, flutters, or rolls. approximately 6,000 movements in every 2-hour period.	Within a span of 12 hours, there should be 12. maximum of 6,000 movements every 2 hours.	>12 movements Such as kicks, flutters, or rolls. within 12 hours; >6k/2hrs
Blood glucose (2-hour glucose) [37]	<7.9 (<140) mmol/l(mg/dl)	<7.9 (<140) and≥7.9(≥140) mmol/l(mg/dl)	≥11.2(≥200) mmol/l(mg/dl)

BMI [3]	(18.6–24.8 kg/m2)	(18.6–24.8 kg/m2)	Underweight is defined as a BMI of less than 18.6 kg/m². Overweight is defined as a BMI of 25-29.9 kg/m², while obesity is defined as a BMI of 30-34.9 kg/m².
HbA1c, blood glucose[1]	<42 mmol/mol	42-46 mmol/mol	≥48mmol/mol
Blood glucose (Fasting glucose) [1]	<6.2 (<110) mmol/l(mg/dl)	≥6.2(≥110)& <7.1(<126) mmol/l(mg/dl)	≥7.1 (≥126) mmol/l(mg/dl)

3.2 Assured Analysis of Risk Factors in a Diabetes Dataset for Females

This research involved a thorough analysis of an existing dataset of diabetes patients. The data was extensively preprocessed, filtered, and categorized with the aid of medical experts and an extensive literature search. As a result, the risk factors were accurately identified and categorized with a high degree of confidence. After conducting a thorough analysis of an extensive dataset of patients with diabetes, the risk factors were expertly categorized with the assistance of medical professionals and in-depth literature research. Preprocessing and filtering were also utilized to ensure the accuracy and reliability of the findings.

The University of Waikato in New Zealand has developed an exceptional data mining software called Weka. With its state-of-the-art algorithms and imaging tools for data preprocessing, it is undoubtedly a valuable and powerful tool for classification, regression, visualization, clustering, and feature selection tasks.

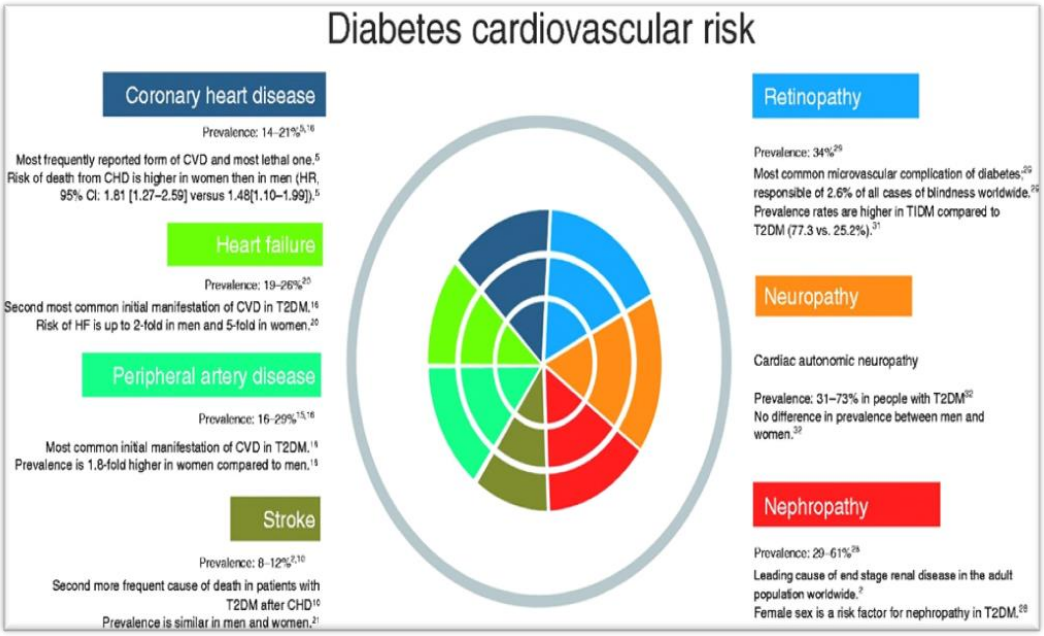

Fig.1 Exploration of Cardiovascular Complications in Diabetes and Associated Trends[4]

This aggregate was then subjected to a subsequent winnowing process wherein the number of pertinent articles was further pruned, taking into consideration an examination of titles and abstracts. This rigorous screening procedur culminated in a refined cohort of 96 articles that were deemed particularly relevant to the focus of the review. The visual depiction of the adopted methodologies is elegantly encapsulated within Figure 4, offering a graphical representation of the material and methods pursued throughout the course of this research

3.2.1 Evaluating the Precision of Real Data Samples through Analysis.

IoT devices are reliable in collecting accurate health data of pregnant women, which is then verified by medical experts. The devices promptly send notifications to both the women and their families about their health conditions and risk levels. With the help of algorithms developed by medical professionals, the risk level of each pregnant woman is precisely determined. The LMT algorithm has been proven to exhibit the highest accuracy in detecting pregnancy risk levels, not just for the training set data but also for cross-folding validations. It can be confidently stated that the LMT algorithm is the most accurate in detecting pregnancy risk levels based on the dataset of risk parameters. The text discusses a comprehensive evaluation of maternal and infant health monitoring systems, which highlights the effectiveness of IoT devices in gathering accurate health datasystems is conducted in this section, adhering to the sequential plan depicted in Figure 4.The exploration embarks with an in-depth analysis of maternal healthcare systems, elucidating the nuances of the sensors harnessed and the AI/ML methodologies deftly employed.

In a seamless transition, the examination seamlessly pivots to infant healthcare systems, casting a discerning gaze on the spectrum of sensing technologies underpinning their function and the intricate array of AI/ML techniques that find adept application. This thorough discussion is presented in two consecutive parts. Segment 5.3 focuses on sensing technologies, while Segment 5.2 delves into the diverse realm of AI/ML methodologies, as depicted in Figure

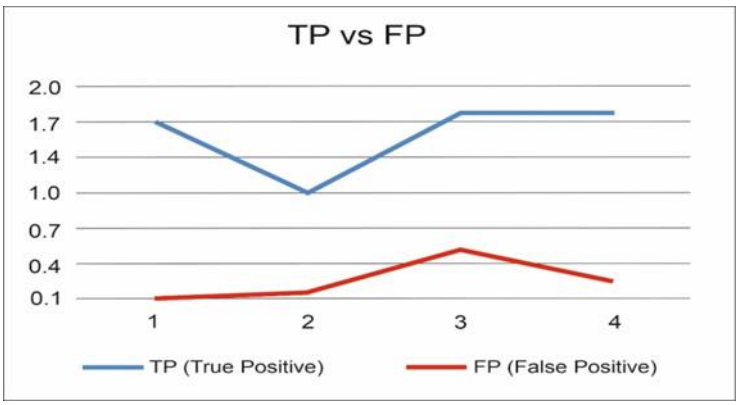

Fig. 2. Outcome of logistic model tree on the Given Dataset.

3.3 Below are the experimental findings from the analysis of the Indian diabetes dataset.

3.3.1 Accuracy of Classification

In Figure 2, the LMT algorithm is applied to the existing dataset and achieves an accuracy of almost 98%. LMT is a combination of logistic regression and tree-based machine learning algorithms. The y-axis of the bar chart represents the risk intensity levels of the existing dataset, which are labeled as 3 for high-level risk, 2 for mid-level risk, and 1 for low-level risk for better representation of the results.

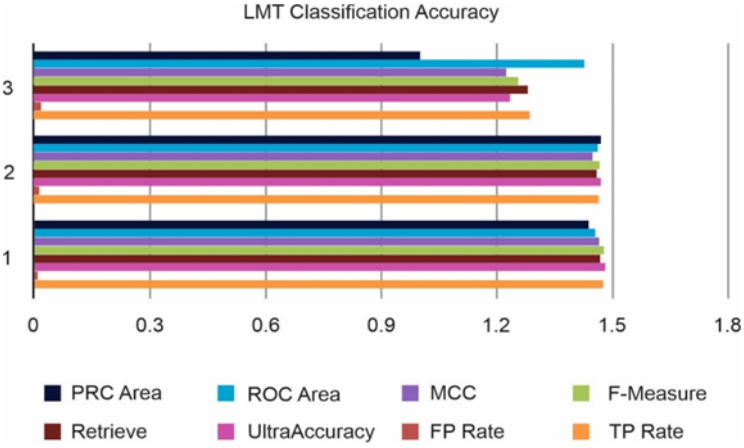

Fig.3. Brief Summary of Classification Accuracy Results for an Existing Dataset.

The confusion matrix clearly shows the true positive and false positive rates, with a very low false positive rate maximizing the accuracy and performance of the algorithm for this dataset.

Decoding Performance		High	Lower	Mid
Anticipated Outcome	Lower	**630**	0	9
	Mid	0	**567**	8
	High	4	6	**89**

3.3.2 Making Predictions using LMT

LMT is a highly effective tool for predicting risk levels with great accuracy. The model was trained using the available dataset and then tested on data from five new patients producing absolutely error-free results, as shown in Fig. 3. To categorize the risk level, Table 1 is the perfect reference point. Our LMT model has unmatched accuracy in predicting risk levels. It was trained on existing datasets and tested on five new patient data with error-free results (Fig. 2). Table 1 serves as the definitive reference point for risk level categorization.

The alarming prevalence of premature births has introduced significant health challenges for infants, necessitating prolonged stays in incubator systems. However, manual monitoring proves arduous, prompting the integration of cloud computing, IoT, and wireless medical sensors to enhance healthcare management. A new system was introduced to ensure doctors' and incubator monitoring system's accuracy and security, guarding against impersonation and replay attacks.

This system aims to implement an efficient authentication protocol with a new encryption scheme to continuously monitor infants' vital signs. It reduces the need for nurses and doctors and optimizes cost-effectiveness and performance while maintaining strict security measures. I am confident that the proposed encryption scheme is an excellent solution. It effectively enhances computation efficiency while maintaining the utmost security of the information.Friendly The analysis of various types of data continues to yield valuable insights in the field of epilepsy research. An intriguing work has been conducted, comparing wristband data to seizure surrogate data, with promising results in the understanding and prediction of seizures. It is truly remarkable how technology can aid in the management and comprehension of medical conditions. The research revealed distinct differences in signals between preictal and inter-periods, which could be used to develop individualized seizure markers. The Electronic Design Automation (EDA) signal entropy proved to be an efficient way to improve seizure detection in a subset of patients. This approach provided us with valuable insights into seizure pathophysiology and ANS functionality while keeping costs low.

4. Proposed System Model

4.1 Flow Diagram of Integrated Model

In order to ensure the well-being of pregnant women, it is imperative to diagnose and treat them with timely medical attention and provide them with proper medication. To this end, our proposed model has been developed to offer better and real-time medical care at a lower cost. As depicted in Figure 5, the system model is designed to provide efficient and effective medical care to pregnant women, and we are confident that it will significantly improve the quality of care they receive...

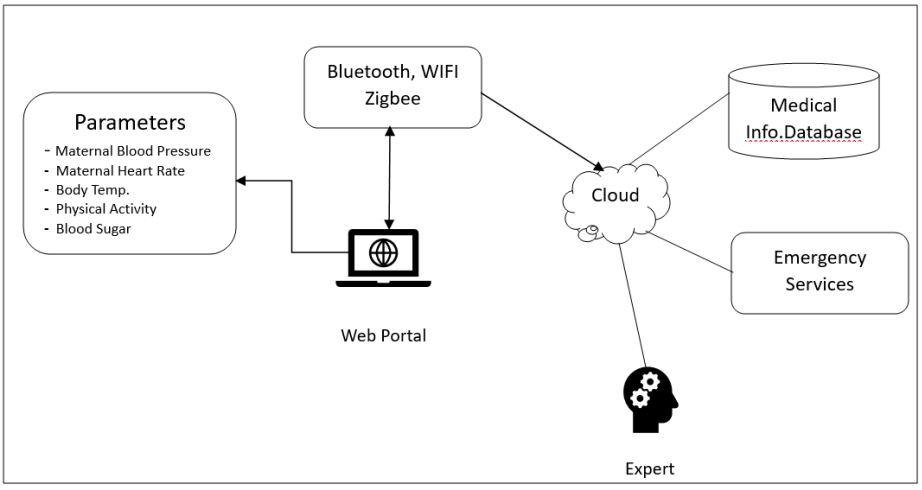

Fig. 4. Proposed system model

Our proposed system model has a crucial goal of reducing maternal mortality rates while providing better care for pregnant women residing in rural areas. However, most hospitals use expensive, non-portable, and sophisticated devices. To address this issue, we aim to develop a compact and efficient assist system that can assess the vital signs of both rural pregnant women and the fetus using RFID tags that are wearable sensing devices.In regions undergoing development, the prompt diagnosis of pneumonia remains a rarity.

Although lung ultrasound serves as a valuable diagnostic tool, its utility is constrained by the requirement for skilled personnel. To surmount these limitations, an automated classification methodology for pneumonia was introduced in [23].

4.2 IoT Device Model and Results

The system shown in Fig. 5 accurately displays patients' temperature, pulse, and heart rate readings, and the same is being alerted on mobile, as depicted in Fig.6.

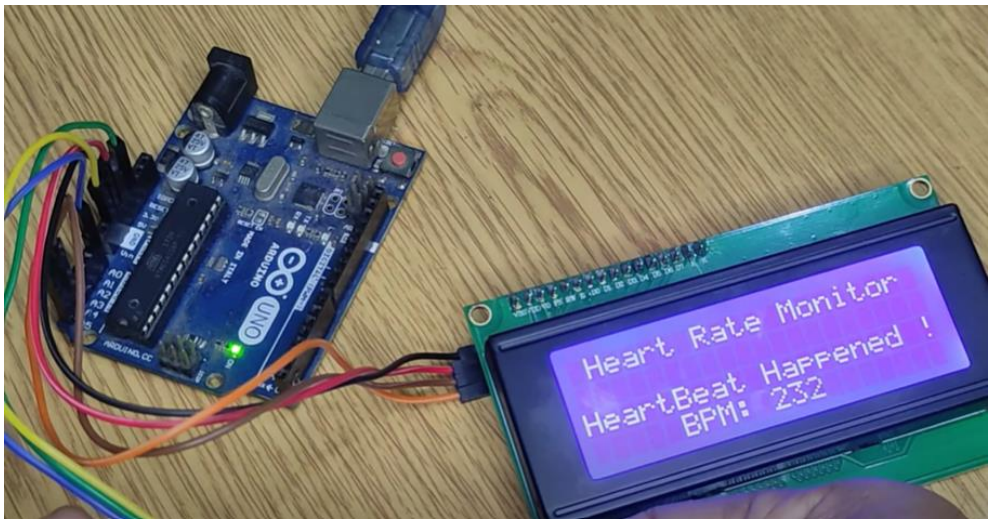

Fig.5. Collecting heart rate and pulse information through the utilization of Arduino Mega 2560, alongside ECG and heartbeat sensors.

Fig.6. Real-Time Alert to caregivers and doctors

The approach involves the removal of skin and tissue artifacts from lung ultrasound frames, followed by the analysis of these frames utilizing an Artificial Neural Network (ANN). This ANN is trained to accurately discern healthy lungs from infected ones using a dataset of 60 ultrasound frames.

The outcomes illustrate that the proposed approach attains a sensitivity of 90%, suggesting its potential in constructing an operator-independent system for timely pneumonia diagnosis.

The fundamental architecture of locomotion is unveiled through the earliest motor skills of an infant, serving as determinants of developmental progression. Conversely, motor dysfunction exerts adverse effects on spatial awareness, equilibrium, and cognition, with notable significance in the context of infants with autism spectrum disorder (ASD). ASD is associated with delays in sitting, standing, and head control.

The presented system harnesses a wireless apparatus named Opal sensors are highly advanced devices that possess a complex 3D structuremagnetometer, 3D gyroscope, and 3D accelerometer, to comprehensively analyze the infant's movement patterns throughout the day. These sensors gauge the intricacy of motion in infants—an imperative parameter

for normative motor development, given that reduced bodily movement can signal ASD symptoms.

The detection of human well-being and development through high-resolution, sensitive image sensors is commonplace in the contemporary age. Nevertheless, these biological and environmental sensors prove costly and demand robust processing capabilities. Consequently, analyzing human activity during routine daily life at home poses a significant challenge. Confronting these obstacles, a detection mechanism is proposed, harnessing low-cost infrared (IR) technology-based sensors for location, thermal environment, motion, and temperature [42]. This technology proves beneficial for long-term monitoring within a domestic environment.

The latest technique was evaluated for visualizing the thermal milieu and parental influences on the common marmoset's circadian rhythms. Initially, a comparative assessment was made against manual analysis for design validation.

5. Conclusion

Sensor-based frameworks have revolutionized healthcare systems, enabling timely medical assistance to patients in remote and underserved rural regions. The advent of wireless technology has facilitated the remote monitoring of maternal and infant health conditions through sensor utilization, enabling early detection of potential issues. Recent advancements in the realm of Artificial Intelligence (AI) have further empowered these healthcare systems, enabling predictive capabilities and providing valuable diagnostic support to medical practitioners. Leveraging Internet of Things (IoT) applications, these systems offer swift and precise disease diagnoses, addressing challenges such as storage, cost, and latency. In this research, medical experts identified and categorized various risk factors. Machine learning algorithms were utilized to classify and predict risk levels in an existing dataset The risk level prediction was flawlessly executed in both instances, owing to seamless coordination with IoT-enabled devices to gather sample data. Crowdsourcing can be used to analyze and broadcast risk factors, improving health monitoring for patients and their families.

This investigation delves into maternal and infant-focused healthcare systems, meticulously examining and categorizing them based on sensor deployment and Machine Learning (ML) techniques as delineated in the latest scholarly works.

A comprehensive exploration of wearable sensors and IoT devices utilized for health monitoring is conducted, encapsulating their salient attributes and their specific applicability to maternal and infant health concerns. Moreover, intelligent and anticipatory algorithms are expounded upon, offering a profound insight into the cutting-edge research endeavors within this domain.

Smart healthcare services have a wide range of capabilities, including the ability to generate alerts through multiple computing platforms such as cloud, fog computing, and edge computing. Additionally, a compilation of real-world datasets is provided, encompassing attributes, size, format, and other essential details, serving as a valuable resource for researchers in quest of suitable datasets for their investigative pursuits. The exploration unveils a notable scarcity of available real-world datasets within this field.

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