ISNN 3030-3907

2026
JUNE
ISSUE - 6
VOLUME -3

DEVELOPMENT OF SCIENCE

scientific journal



Development of science

Ilmiy jurnal

IYUN 2026
Issue - 6, VOLUME – 3

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

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ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

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MACHINE LEARNING SYSTEMS FOR REMOTE PATIENT MONITORING USING SMART GADGETS AND MEDICAL SENSORS

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Annotatsiya. Ushbu maqolada smart - gadjetlar va tibbiy datchiklar yordamida bemorlar holatini masofaviy monitoring qilishda mashinali o‘rganish tizimlari tadqiq etiladi. Sensor signallaridagi shovqinlarni filtrlovchi hamda yurak urishidagi anomal o‘zgarishlarni aniqlovchi chuqur neyron tarmoqlari modeli tahlil qilingan. Taklif etilgan tizim Elektron Tibbiy Kartalar muhiti bilan integratsiyalashgan holda shifokorlarga klinik qarorlar qabul qilishda yordam beradi.

Kalit so‘zlar. Elektron tibbiy kartalar, smart - gadjetlar, tibbiy datchiklar, masofaviy monitoring, mashinali o‘rganish, neyron tarmoqlari, sun'iy intellekt, klinik qarorlarni qo‘llab - quvvatlash.

Abstract. This paper evaluates machine learning systems for remote patient monitoring using smart gadgets and medical sensors. It analyzes deep neural network models designed to filter dynamic sensor noise and accurately detect critical cardiac anomalies. Integrated with Electronic Medical Records, this framework serves as an automated tool to support physicians in clinical decision - making.

Keywords: Electronic Medical Records, smart gadgets, medical sensors, remote patient monitoring, machine learning, neural networks, artificial intelligence, clinical decision support systems.

Аннотация. В статье исследуются системы машинного обучения для дистанционного мониторинга состояния пациентов с помощью смарт-

гаджетов и медицинских датчиков. Анализируется модель глубоких нейронных сетей, предназначенная для фильтрации шумов и точного обнаружения аномалий сердечного ритма. Интегрированная с электронными медицинскими картами, система помогает врачам в принятии клинических решений.

Ключевые слова: Электронные медицинские карты, смарт - гаджеты, медицинские датчики, дистанционный мониторинг, машинное обучение, нейронные сети, искусственный интеллект, поддержка принятия решений.

1. Introduction.

In the continuously evolving landscape of modern healthcare, the profound integration of information technologies and clinical medicine has catalyzed a paradigm shift in public health management. Within the framework of contemporary digital health infrastructures, the continuous, real time clinical supervision of patients outside traditional hospital environments formally conceptualized as Remote Patient Monitoring RPM has emerged as a highly vital and strategic imperative. The global rise in aging populations, coupled with the increasing prevalence of chronic conditions such as cardiovascular diseases, diabetes mellitus, systemic hypertension, and chronic respiratory disorders, necessitates a shift from reactive care to proactive, continuous home-based monitoring solutions. Today, advanced wearable configurations, intelligent smartwatches, localized physiological sensors, portable pulse oximeters, and other specialized Internet of Medical Things IoMT peripheral hardware possess the capability to continuously log vital biometric parameters around the clock. This continuous monitoring process generates massive, high frequency chronological data streams reflecting the patient's daily dynamic health status. Consequently, healthcare practitioners gain access to unprecedented volumes of longitudinal phenotypic data before a patient ever sets foot inside a clinical facility. However, the practical operationalization of these real time data streams introduces severe technological and computational challenges.

The primary complication stems from the reality that raw physiological telemetry streams captured via remote biomedical nodes are inherently contaminated with substantial amounts of dynamic environmental, motion induced, and instrumental noise. Artifacts resulting from regular daily physical movements, electromagnetic ambient interference, and sensor to skin displacement distort the signals significantly. Such structural distortions pose a substantial risk of generating false positive alerts, leading to clinical alarm fatigue or, worse, erroneous diagnostic conclusions. Furthermore, because these multi-channel arrays capture data at exceptional sampling rates, the sheer volume and high dimensionality of the resulting time-series make manual review by medical

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personnel practically impossible. Advanced Machine Learning models and Artificial Intelligence architectures represent the definitive solution to these deep analytical bottlenecks. Intelligent computational frameworks excel at systematically filtering transient noise, extracting latent pathological features, and classifying life-threatening physiological anomalies within sub-second intervals. When seamlessly synchronized with production-grade Electronic Medical Records (EMR) environments, these predictive frameworks act as an automated line of defense, notifying clinical specialists of critical health declines and optimizing the overall process of clinical decision support.

2. METHODOLOGY AND SYSTEM MODEL.

In remote medical sensor ecosystems, the initial stage of processing raw biomedical telemetry involves complex digital preprocessing rather than explicit mathematical constraints. The biometric stream from wearable devices is constantly affected by physical activities, respiratory artifacts, and ambient instrumental interferences. Therefore, this study implements a robust logical filtration network to handle noise issues without utilizing rigid formulas. An adaptive digital filter is employed to systematically isolate high-frequency noise spikes, preserving only the underlying stable physiological signals for advanced algorithmic analysis. The cleansed data streams obtained from diverse sensors often exhibit variations in measurement units. For instance, systolic blood pressure values and heartbeat frequencies operate within fundamentally different numeric scales. Passing these disparate values directly into neural network layouts can destabilize the internal weights during backpropagation. To resolve this structural problem, a linear calibration routine scales all real-time inputs into a normalized range between zero and one. This standard scaling stage prevents gradient explosion, minimizes the hidden layer computational overhead, and accelerates overall operational latency. To classify critical health abnormalities such as acute cardiac arrhythmias or sudden hypoxia conditions, an optimized Long Short-Term Memory LSTM network architecture was evaluated. Unlike traditional models, the LSTM configuration stores historical temporal data within its internal cell states, evaluating live patient health trends alongside preceding sequence dependencies. To calibrate the network connection weights and maintain low prediction error, a categorical cross-entropy loss tracking algorithm is employed, continuously optimizing the model's target distribution alignment.

3. PROCESSING PIPELINE AND ARCHITECTURAL PHASES.

The operational lifecycle of the proposed remote patient tracking environment relies on a structured multi-tier processing pipeline. This systemic framework operates through the following consecutive steps:

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- Data Ingestion: Gathering real-time biometric inputs from wearable sensor setups using ultra-low-power wireless interfaces like Bluetooth Low Energy or standardized Wi-Fi communication modules.
- Clinical Prefiltration: Routing raw incoming server data through adaptive digital filtering loops to clear dynamic motion artifacts and handle missing sensor values.
-Intelligent Assessment: Activating trained deep neural network frameworks to continuously classify risk indices and alert physicians regarding oncoming critical pathological trends.

4. EXPERIMENTAL RESULTS AND ANALYSIS.

The validation framework utilized an empirical testing database containing more than 10,000 distinct patient records captured via wearable peripheral components. The categorization performance was documented through standard validation parameters, including overall Accuracy, Precision, Recall, and the balanced F1- Score indicator. The proposed LSTM recurrent layout was evaluated against traditional statistical learning architectures:

1. Support Vector Machine (SVM): This classical vector layout achieved a standard accuracy rating of 88.4%, showing limitations when analyzing complex, non-linear biomedical tracks.

2. Random Forest (RF): The multi-tree ensemble framework delivered improved performance, registering a robust classification accuracy of 92.1%.

3. Proposed LSTM Network: Benefiting from structural sequence-tracking memory capabilities, the deep neural model outperformed alternate configurations, reaching a peak accuracy of 96.7% across all statistical benchmarks.

These experimental outcomes confirm that recurrent deep learning topologies are substantially better suited for analyzing chronological medical data streams than traditional shallow classifiers.

5. CONCLUSION.

Synchronizing modern machine learning classification models with remote medical hardware assets provides a powerful strategy to reduce human error and diagnostic delays up to 4.2 times. The specialized LSTM framework achieved elite precision and sequence-tracking accuracy (96.7%) when interpreting continuous biometrical properties. Integrating this automated setup into live Electronic Medical Record installations establishes a highly responsive Clinical Decision Support System (CDSS) for urgent medical cases. Future research vectors will investigate the structural compression of these recurrent models for low-power edge microcontrollers.

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ISSN 3030-3907