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ARTIFICIAL INTELLIGENCE-BASED METHODS FOR EARLY DISEASE DIAGNOSIS

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Introduction. Over the past decade, Artificial Intelligence (AI) technologies have brought revolutionary changes to the field of medicine. Early disease detection is one of the top priorities in healthcare, playing a crucial role in improving treatment effectiveness and prolonging patient survival. Traditional diagnostic methods often require significant time, are subject to human interpretation, and in some cases, increase the risk of late detection. For this reason, AI-powered automated early diagnosis systems have gained considerable scientific and practical attention in recent years. These systems analyze vast amounts of medical data — including X-ray images, MRI scans, genetic information, and laboratory results — to identify complex patterns that may be beyond human perception or experience.

Data acquisition. The primary input for the system is medical data, which may include images (X-ray, MRI, CT), laboratory test results, genetic sequences, or clinical observations. Modern systems often adopt a “multimodal” approach, integrating multiple types of data for improved accuracy.

Preprocessing. Before being fed into the AI model, data undergoes preprocessing to enhance quality. This may involve noise reduction, brightness and contrast normalization, format conversion, and resizing. In image-based diagnostics, this step is critical to ensure that subtle disease indicators are not obscured by background noise.

Feature extraction. At this stage, the model identifies disease-specific features from the data — for example, tissue density variations, tumor shapes, or vascular changes. Deep learning algorithms, particularly convolutional neural networks (CNNs), are highly effective here, automatically learning hundreds of relevant parameters from the images.

Model training. During training, the system is fed “labeled” datasets — samples where the presence or absence of a disease is already known. The algorithm learns to detect hidden patterns in the data that correlate with the condition. Parameters are optimized to maximize predictive accuracy.

Validation and testing. The trained model is evaluated using previously unseen data. Metrics such as accuracy, sensitivity (recall), specificity, and AUC (Area Under the Curve) are used to measure performance.

Result interpretation. The output is usually expressed as a probability (e.g., “Pneumonia probability: 87%”). These results serve as a decision-support tool for physicians. Some systems also provide interpretability tools such as heatmaps or attention maps to highlight the areas of interest that influenced the AI’s decision.

AI-based early diagnosis systems can be classified into several main categories based on their methodology and the type of data they process. Each type has its own strengths, application areas, and technological requirements.

Image-based diagnostic systems.

Description: These systems analyze medical images such as MRI, CT, X-rays, and ultrasound using deep learning algorithms.

Applications: Detection of cancer (breast, lung, brain tumors), cardiovascular diseases, and bone fractures.

Advantages: Ability to detect subtle changes in images that may not be visible to the human eye.

Database-driven diagnostic systems

Description: Analyze digital medical records, laboratory test results, and symptom databases.

Applications: Prediction of metabolic and chronic diseases such as diabetes, heart failure, and liver disorders.

Advantages: Uses large-scale statistical data to forecast disease progression and risk.

Genomics and proteomics-based diagnostic systems

Description: Process DNA and RNA sequences as well as protein analysis using AI models.

Applications: Identification of hereditary diseases, genetic mutations, and personalized drug selection.

Advantages: Enables detection of diseases at the molecular level.

Multimodal diagnostic systems

Description: Combine multiple sources of information — images, lab results, genetic data, and patient history — for integrated analysis.

Applications: Complex diseases (e.g., rare cancer types) or multi-organ system disorders.

Advantages: Improves diagnostic accuracy by synthesizing diverse data sources.

Artificial intelligence-based early diagnosis technologies offer several notable advantages over traditional diagnostic approaches, making them an integral part of modern healthcare. One of the most significant strengths is their high accuracy. Machine learning and deep learning algorithms, trained on large datasets, can detect subtle morphological or biochemical changes that may remain unnoticed by the human eye. This capability significantly reduces the probability of misdiagnosis.

Speed is another critical benefit. While conventional laboratory or imaging analyses may require substantial time, AI-powered systems can deliver results within seconds or minutes. This is particularly important in emergency care, where rapid decision-making can be life-saving.

Moreover, AI systems possess the capacity to process vast amounts of data simultaneously. Thousands of medical images or laboratory records can be analyzed within minutes, surpassing human capabilities in both scale and speed. Consistency of performance also plays a vital role, as AI reduces errors associated with human factors such as fatigue, loss of concentration, or subjective bias, thereby ensuring stable and reliable outcomes.

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In addition, AI enhances the possibilities for personalized medicine. By taking into account a patient's unique clinical and genetic characteristics, it can contribute to the development of tailored treatment strategies — a feature particularly beneficial in oncology and genetic disorders. When integrated with IoT, AI systems also enable real-time remote monitoring of patient health, further expanding their practical applications in preventive and continuous healthcare.

To demonstrate the practical aspects of AI-based early diagnosis technology, a simple working example is presented. This example outlines the process of detecting disease indicators from a medical image. The model used is a pre-trained deep learning architecture such as MobileNetV2 or ResNet. These architectures are recognized for their efficiency and speed in image processing, making them particularly suitable for real-time clinical applications.

The process begins with loading and preprocessing the image. The image is resized to the required dimensions, pixel values are normalized, and the data is prepared for model input. The model then analyzes the image and outputs a probability indicating the presence or absence of disease-related features. For instance, when analyzing a chest X-ray, the output could read "Pneumonia probability: 87%" or "Healthy lungs probability: 95%."

The following Python code snippet illustrates a simplified version of this process. It uses a pre-trained model within the TensorFlow library to perform the analysis.

```
import tensorflow as tf
import numpy as np
from tensorflow.keras.preprocessing import image
# Load pre-trained model
model = tf.keras.models.load_model("disease_model.h5")
# Load and preprocess the image
img_path = "test_image.jpg"
img = image.load_img(img_path, target_size=(224, 224))
img_array = image.img_to_array(img)
```

```
img_array = np.expand_dims(img_array, axis=0) / 255.0
# Predict
prediction = model.predict(img_array)
prob = prediction[0][0]
if prob > 0.5:
    print(f"Disease detected, probability: {prob*100:.2f}%")
else:
    print(f"No disease detected, probability: {(1-prob)*100:.2f}%")
```

This approach enables automation of the diagnostic process, reduces human error, and significantly shortens analysis time. In its extended form, such systems can integrate not only image data but also laboratory test results, genetic information, and clinical records, thus enabling more comprehensive and accurate diagnosis.

Artificial intelligence-based early diagnosis technologies are widely applied across multiple fields of medicine. In radiology, AI algorithms analyze X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) scans to assist physicians in detecting lung cancer, brain tumors, cardiovascular diseases, and bone fractures. These systems are capable of identifying extremely subtle changes that may not be visible to the human eye, enabling detection at the earliest stages.

In oncology, AI is used to analyze biomarkers and process genetic data to determine the molecular characteristics of tumors. This allows for the personalization of treatment strategies based on an individual's genetic profile. AI algorithms are also employed to monitor the effectiveness of chemotherapy and radiotherapy, facilitating timely adjustments in treatment plans.

In infectious disease diagnostics, AI systems enable rapid detection of viruses and bacteria based on laboratory test data. During the COVID-19 pandemic, AI technologies were effectively used in many countries to detect the virus and predict its spread dynamics.

In cardiology, AI assists in the real-time analysis of electrocardiogram (ECG) signals to detect arrhythmias, heart failure, and other cardiovascular conditions. Moreover, AI plays an important role in telemedicine platforms, enabling continuous remote monitoring of patients' health status.

The future of AI-based early diagnosis technologies is expected to expand significantly within the medical field. The integration of artificial intelligence (AI) with Internet of Things (IoT) technologies will greatly enhance the ability to monitor patient health remotely and in real time. Such systems will not only detect existing diseases but also assess the risk of disease development, allowing for the initiation of preventive measures at an early stage.

In the coming years, smart medical devices and wearable technologies will become increasingly widespread for continuous health monitoring. Physiological parameters such as heart rate, blood pressure, blood oxygen level, and others will be measured in real time and automatically analyzed by AI algorithms. The results will be transmitted to healthcare providers, enabling timely medical interventions when necessary.

Significant advancements are also expected in the fields of genomic analysis and personalized medicine. By analyzing genetic data, AI algorithms will be able to predict not only existing conditions but also potential future diseases, thus enabling the development of individualized prevention and treatment strategies.

In the future, many of these systems will be deployed via cloud computing infrastructures, making them accessible and applicable on a global scale. Consequently, AI-based early diagnosis technologies will not only accelerate diagnostic processes but also elevate preventive medicine to an entirely new level.

Artificial intelligence-based early diagnosis technologies represent one of the most promising areas in modern medicine. Their high accuracy, rapid processing capabilities, and ability to handle large volumes of data make it possible to detect diseases at their earliest stages. These systems not only automate the diagnostic process but also reduce human error and enhance treatment effectiveness.

The application of AI in personalized medicine, genomic analysis, radiology, cardiology, and infectious disease diagnostics demonstrates its versatility. In the future, the integration of AI with IoT technologies will further enhance remote monitoring, prevention, and individualized treatment strategies. Thus, AI-powered early diagnosis systems are steadily establishing themselves as essential tools for improving quality, speed, and reliability within healthcare systems.

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