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AI-Driven Personalized Medicine: Predictive Genomics and the Future of Patient-Centric

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Abstract

The most transformative applications of artificial intelligence in healthcare today are AI-driven personalized medicine, particularly in predicting genetic disease patterns. It assembles genomics, big data analysis, and predictive modeling to shift medicine from a "one-size-fits-all" method to individualized patient care.

Artificial Intelligence (AI) plays a vital role in forming personalized medicine by linking genomics, biomedical data science, and clinical decision-making. Research indicates that machine learning (ML) and deep learning (DL) models are revolutionizing healthcare, transitioning from standardized treatments to personalized, predictive therapies. AI tools analyze large genomic datasets, electronic health records, and medical images to determine genetic patterns, disease markers, and treatment targets with significant accuracy. Generative AI models, such as GANs and VAEs, are further enhancing disease modeling and generating artificial patient data for specified simulations.

This research focuses on building an AI-driven predictive model that can examine large-scale genomic datasets to predict disease risks. Using machine learning algorithms such as Decision Tree, K-Nearest Neighbors (KNN), Support Vector Machine (SVM), and Logistic Regression, the model research aims to analyze genetic patterns to diseases based on key biomarkers and patient history. The proposed predictive model provides early detection and treatment planning, covering the gap between raw genomic datasets and action-based clinical insights. The result of this research focuses on supporting healthcare professionals in giving data-driven, patient-specific medical care.

Keywords: Artificial Intelligence (AI), Personalized Medicine, Predictive Genomics, Machine Learning (ML), Pharmacogenomics

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Introduction:

Initiated medicine plays a vital change in changing traditional healthcare to a system that modifies treatment and preventive strategies for specific patients based on their genetic, clinical, and lifestyle information. This variation has come from progress in genomics, molecular biology, and data analysis. Nevertheless, the increasing amount and difficulty level of medical data have beaten traditional methods. This research gap has unlocked the gate for Artificial Intelligence (AI) to become an essential tool in precision healthcare.

Artificial intelligence (AI) and machine learning (ML) analyses large datasets, determine intricate patterns, and build predictive models with high accuracy, offering solutions to cover the research gap. Application of ML algorithms like Decision Tree, K-Nearest Neighbors (KNN), Support Vector Machine (SVM), and Logistic Regression to genomic datasets can lead to a predictive model that can determine disease risks, uncover hidden correlations, and help clinicians in building personalized treatment schedules. Using AI-driven predictions, clinicians can predict disease risks, build personalized treatment plans, and enhance patient outcomes.

This research helps to solve issues related to limited data, diversity, and privacy. This research and experiment focuses on building and maintaining AI-driven models for predictive genomics, also focuses on improving early detection of disease risks, précised medicine, and clinical decision support.

Literature Review:

Mishra and colleagues highlighted the vital impact of Generative Artificial Intelligence (GAI) in precision medicine. They discussed how GANs, VAEs, and Large Language Models (LLMs) help predict drug responses, discover biomarkers, and simulate diseases with synthetic but realistic datasets. These techniques improve medical insights while protecting data privacy.

However, challenges like data bias, model transparency, and validation remain significant obstacles to clinical use.[1]

This study explored AI's role in pharmacogenomics, emphasizing how machine learning and deep learning enhance drug dosage prediction, reduce adverse reactions, and support personalized therapy. The authors stressed the importance of ethical governance, regulatory frameworks, and data integration to ensure reliable AI applications in clinical settings.[2]

Garg's research examined Generative AI models like GANs, VAEs, and transformer-based structures (e.g., GPT) for drug discovery and treatment recommendations. These systems help create synthetic patient data and flexible therapeutic pipelines. However, Garg pointed out the limits of black-box models, data authenticity, and multimodal integration, urging the use of explainable AI frameworks for responsible deployment.[3]

Mondal identified AI in genomics as a key driver of modern precision medicine. ML and DL models improve mutation identification, variant interpretation, and genomic prediction. The study acknowledged ethical and technical challenges like data security and algorithmic transparency, which must be addressed for broader use.[4]

This paper proposed an AI-based framework that integrates genomic, clinical, and environmental data to optimize treatment plans. It employed predictive modelingsss and reinforcement learning to enhance real-time medical decision-making, emphasizing interoperability, explainable AI, and ethical accountability in healthcare.[5]

Their study discussed AI applications in genomics, diagnostics, and drug discovery, providing examples like IBM Watson Oncology and DeepMind's AlphaFold. They addressed challenges such as algorithmic bias, data privacy, and gaps in regulation, suggesting blockchain, federated learning, and explainable AI as potential solutions.[6]

Together, these studies show that AI and ML are essential for achieving predictive, preventive, and precision healthcare. By combining genomics, electronic health records, and deep analytics, AI improves diagnosis and treatment efficiency while requiring stronger ethical and policy frameworks for sustainable use.[7]

This paper focused on AI-driven genomics in India, suggesting the integration of Indi Genome and Pharm GKB datasets for region-specific precision medicine. Using Random Forest models and simulated data (BRCA1, BRCA2, TP53), it demonstrated treatment prediction and health recommendations. The study emphasized dataset standardization, population-specific diversity, and ethical AI governance as crucial for successful implementation.[8]

Problem Definition:

Despite rapid advancements in genomics and data analytics, traditional healthcare systems struggle to translate massive genomic and clinical datasets into actionable insights for personalized treatment. There is a critical need for an AI-driven predictive model that can accurately analyze genetic data, identify disease risks, and suggest individualized therapeutic strategies. This research aims to develop and evaluate machine learning models for predictive genomics, enabling early diagnosis and precision medicine.

Objectives:

1. To develop an AI-based predictive framework that analyses genomic and clinical data for identifying potential disease risks.
2. To implement and compare multiple machine learning classification algorithms (KNN, SVM, Logistic Regression, and Decision Tree) for genomic data prediction accuracy.
3. To evaluate model performance based on accuracy and reliability in predicting patient-specific outcomes.
4. To integrate predictive genomics insights for enhancing decision-making in personalized healthcare and treatment planning.
5. To explore future enhancements using deep learning, federated learning, and real-time data integration for scalable clinical applications.

Methodology:

This research paper examines the experimental research design, using machine learning classification algorithms, preferring prediction of genomic and clinical data to predict disease risks and design individualized treatments.

This research predicts accuracy using a dataset of 4500 (values), including features like joint pain, fatigue, skin rash, weight loss, and mood swings.

KNN: (K-Nearest Neighbors) is a supervised learning algorithm that predicts values based on the average of the nearest neighbors.

Experiment:

This table includes the dataset trained on the KNN classifier algorithm, along with tuning parameters.

Table 1: KNN CLASSIFIER PREDICTION TABLE:

SR.NO	K -VALUE	TRAIN	TEST	ACCURACY

1	3	0.8	0.2	94.5
2	5	0.7	0.3	92.8
3	7	0.6	0.4	91.6

This table shows the model accuracy for different settings of K value, train-test split, and number of features. The accuracy ranges from 91.6% to 94.5%. Best accuracy: 94.5% (K=3, Train/Test=0.8/0.2).

SVM: Support Vector Machine (SVM) is a supervised machine learning algorithm that builds the optimal hyperplane that best separates data classes with maximum margin.

This table includes the dataset trained on the SVC classifier algorithm along with tuning parameters.

Table 2: SVC PREDICTION TABLE:

SR NO	KERNEL VALUE	TRAIN %	TEST %	ACCURACY %
1	linear	0.8	0.2	96.2
2	rbf	0.7	0.3	95.4
3	poly	0.6	0.4	93.1

This table shows the Support Vector Machine (SVM) model performance with different kernel types (linear, polynomial, RBF), train-test splits, and no of selected features, accuracy ranges. 93.1% to 96.2%. Best accuracy: 96.2% (linear kernel, train/test=0.8/0.2).

Logistic Regression: Estimates the probability of a binary outcome using a logistic (sigmoid) function.

This table includes the dataset trained on the Linear regression algorithm, along with tuning parameters.

Table 3: LOGISTIC REGRESSION PREDICTION TABLE:

SR NO	TRAIN %	TEST %	ACCURACY %

1	0.8	0.2	94.8
2	0.7	0.3	93.5
3	0.6	0.4	91.7

This table shows the Logistic Regression model performance. Best accuracy: 94.8% (train/test=0.8/0.2)

Decision Tree: A Decision Tree is a machine learning algorithm that splits data into branches based on feature decisions to predict outcomes. It creates a tree where each node represents a condition and leaves represent final predictions.

This table includes the dataset trained on the Decision Tree classifier algorithm, along with tuning parameters.

Table 4: DECISION TREE CLASSIFIER PREDICTION TABLE:

SR NO	TUNE PARAMETERS	CHANGE VALUE	ACCURACY %
1	max_depth	3	95.2
2	criterion	entropy	94.3
3	min_samples_split	5	93.8

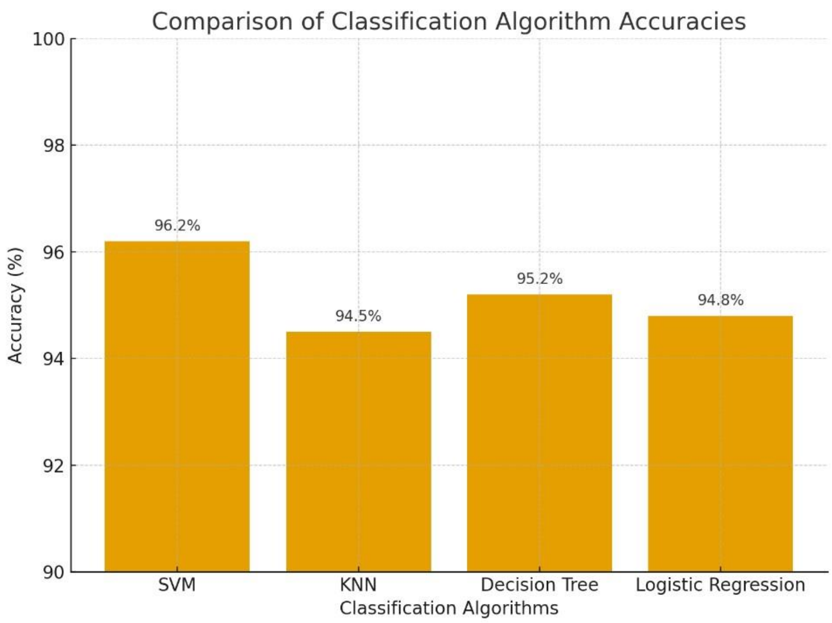
This table shows the Decision Tree model performance with different splitting criteria (gini, entropy) and adept settings. Accuracy range: 93.8% to 95.2%. Best accuracy 95.2% (criterion=absolute error)

Results:

Table 5: This table shows the highest accuracy given by each type of classifier algorithm.

Sr no	*Classifiers*	*Accuracy%*
1	KNN	96.2

2	SVC	94.5
3	Logistic Regression	95.2
4	Decision tree	94.8



SVM Classifier achieves the highest accuracy 96.2% to predict the disease risks.

Conclusion:

This research successfully demonstrates how artificial intelligence and machine learning models can revolutionize personalized medicine by predicting genetic disease risks and optimizing patient-specific treatment strategies. Among the tested classifiers, the SVM model achieved the highest accuracy (96.2%), outperforming KNN, Logistic Regression, and Decision Tree classifiers in genomic data prediction. The integration of AI with predictive genomics enables earlier diagnosis, precision drug design, and improved healthcare outcomes. While the current study focuses on limited genomic datasets, future work can incorporate multi-omics data, deep learning architectures (CNNs, LSTMs), and federated learning to enhance model accuracy, interpretability, and real-time clinical applicability in personalized healthcare.

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