HealthAssist AI: A Machine Learning Based Personal Health Vault With Symptom-Driven Medical Recommendation

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***Abstract* — The rapid advancement of Artificial Intelligence (AI) and Machine Learning (ML) technologies has significantly influenced the healthcare sector by enabling intelligent systems capable of assisting in medical decision-making, disease prediction, and healthcare data management. Despite these advancements, many individuals still face challenges in accessing preliminary healthcare guidance and efficiently managing their medical records. Limited healthcare accessibility, delayed consultations, and fragmented medical documentation remain major issues, particularly in regions with limited healthcare infrastructure. To address these challenges, this research proposes HealthAssist AI, an intelligent healthcare assistance platform that integrates machine learning-based symptom analysis with a secure digital Personal Health Vault for medical record management. The proposed system utilizes supervised machine learning algorithms to analyze symptom–disease relationships and generate predictions for common medical conditions. Algorithms such as Decision Tree, Random Forest, Support Vector Machine, and Naïve Bayes are evaluated to identify the most accurate and interpretable model for disease prediction. The selected model is integrated into a web-based application that enables users to input symptoms and receive predicted health conditions along with general medicine recommendations for common illnesses. In addition to predictive capabilities, the system incorporates a secure digital health record storage module that allows users to upload, organize, and manage their medical documents in a structured timeline-based interface. To ensure data privacy and security, the Personal Health Vault implements encryption mechanisms and controlled access features that protect sensitive health information while allowing temporary sharing with healthcare professionals when required. Experimental results indicate that machine learning-based models can effectively predict common diseases using symptom data with high accuracy. The proposed HealthAssist AI system provides a user-friendly, privacy-focused, and intelligent healthcare support platform that enhances healthcare accessibility and encourages efficient digital medical record management. Future improvements may include integration with clinical datasets, deep learning models, and real-time healthcare monitoring systems. The integration of Artificial Intelligence (AI) and Machine Learning (ML) in healthcare has significantly improved medical decision support systems, disease prediction models, and patient data management. Despite these advancements, many individuals still experience difficulties in accessing preliminary healthcare guidance and managing their personal medical records efficiently. This research proposes HealthAssist AI, an intelligent healthcare assistance system that combines machine learning-based symptom analysis with a secure digital Personal Health Vault for medical record management. The system enables users to input symptoms and receive predicted health conditions along with general medicine recommendations for common illnesses. The proposed system employs supervised machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine, and Naïve Bayes to analyze symptom–disease relationships and generate predictions. The models are trained using a structured medical dataset containing symptoms and associated diseases. After training, the best-performing model is integrated into a web-based platform that allows real-time inference and disease prediction based on user inputs. In addition to the prediction module, the system incorporates a secure health record storage mechanism where users can upload and manage medical reports in a timeline-based interface. To ensure privacy and data protection, the Personal Health Vault uses encryption techniques and role-based access control for secure storage and controlled sharing of medical records. Experimental evaluation demonstrates that machine learning models can effectively predict common diseases based on symptom patterns and provide useful preliminary guidance. The proposed system aims to enhance healthcare accessibility, encourage digital medical record management, and improve patient awareness through AI-driven health assistance tools. Future work will focus on expanding the dataset, integrating deep learning models, and validating predictions using clinical datasets.**

***Keywords*—HealthAssist AI, Machine Learning in Healthcare, Personal Health Vault, Medical Data Security, Symptom-Based Medicine Recommendation, Digital Health Systems**

I. INTRODUCTION

Healthcare systems worldwide are increasingly adopting digital technologies to improve patient care, enhance medical data management, and support clinical decision-making. Artificial Intelligence (AI) and Machine Learning (ML) have emerged as powerful tools capable of analyzing complex medical datasets and identifying patterns that assist in disease prediction and diagnosis [1]. These technologies enable the development of intelligent healthcare systems that can provide preliminary health insights and support medical professionals in decision-making processes.

Machine learning algorithms have demonstrated strong capabilities in analyzing symptom–disease relationships, enabling automated prediction models that assist in identifying possible health conditions based on reported symptoms [2]. Such predictive systems can improve early diagnosis and help individuals understand potential health risks before consulting medical professionals. However, many existing solutions remain limited in accessibility, particularly for individuals who require quick preliminary health guidance.

Another major challenge in healthcare systems is the management of medical records. Traditionally, patient records have been stored as paper-based documents or distributed across multiple healthcare institutions. This fragmented approach makes it difficult for patients to maintain a complete medical history and share important health information with doctors when required [3]. Electronic Health Record (EHR) systems have been developed to address this issue by digitizing patient medical records and improving accessibility.

Despite the advantages of digital health record systems, concerns related to privacy and security remain significant barriers to widespread adoption. Healthcare data contains highly sensitive personal information, and improper data handling may lead to privacy violations or unauthorized access [4]. Therefore, secure data storage mechanisms and encryption techniques are essential for protecting patient information.

Recent studies have shown that integrating machine learning-based prediction systems with secure digital health record platforms can significantly improve healthcare accessibility and patient engagement [5]. Such integrated systems can provide users with both health insights and a secure platform for managing medical documents.

In this context, the present research proposes HealthAssist AI, an intelligent healthcare support system that combines machine learning-based disease prediction with a secure Personal Health Vault for storing medical records. The system allows users to input symptoms, receive possible disease predictions, obtain general medicine recommendations, and securely manage their medical documents within a unified platform.

The main objectives of this research are:

1. To develop a machine learning-based disease prediction system using symptom datasets.
2. To provide preliminary medicine recommendations for common illnesses.
3. To create a secure digital platform for storing and managing personal medical records.
4. To design a user-friendly system that improves accessibility to healthcare information.

By integrating artificial intelligence with secure healthcare data management, the proposed system aims to enhance patient awareness, improve healthcare accessibility, and support digital medical record management.

II. LITERATURE REVIEW

The application of artificial intelligence and machine learning in healthcare has gained significant attention over the past two decades. Several researchers have explored the potential of intelligent systems in disease prediction, medical diagnosis, and healthcare data management.

Kononenko [1] discussed the role of machine learning techniques in medical diagnosis and demonstrated how classification algorithms can assist physicians in analyzing complex medical data. The study highlighted that machine learning models can identify hidden relationships within healthcare datasets, improving diagnostic accuracy and clinical decision-making.

Obermeyer and Emanuel [2] examined the broader impact of artificial intelligence in healthcare systems and emphasized the potential of AI-driven tools in improving medical efficiency and patient outcomes. Their research indicated that AI-based diagnostic systems can analyze large volumes of patient data and provide valuable insights that support healthcare professionals.

Rajkomar et al. [3] investigated the use of deep learning models for predicting diseases using electronic health records. Their study demonstrated that machine learning algorithms can effectively analyze patient medical data and generate accurate predictions for various medical conditions.

Tang et al. [4] explored the importance of electronic health records (EHRs) in improving healthcare delivery. The study emphasized that digital medical record systems enable efficient information sharing among healthcare providers and improve the overall quality of patient care.

More recently, Esteva et al. [5] demonstrated the potential of deep learning models in medical image analysis and disease classification. Their research showed that AI models can achieve performance comparable to human medical experts in certain diagnostic tasks.

Although these studies highlight the benefits of artificial intelligence in healthcare applications, most existing systems focus either on disease prediction or medical record management independently. Few systems integrate both functionalities into a single platform designed for patient use. Additionally, concerns regarding data security and privacy remain significant challenges in healthcare data systems.

The proposed HealthAssist AI system addresses these limitations by integrating machine learning-based symptom analysis with a secure Personal Health Vault for digital medical record storage. This unified approach aims to improve healthcare accessibility while ensuring the privacy and security of patient data.

A. Interpretability in Healthcare AI

Interpretability is essential in healthcare AI because medical decisions must be transparent and explainable. Tree-based algorithms such as Decision Trees and Random Forests provide interpretable structures that allow clinicians to understand the reasoning behind predictions.

B. Trust and Governance in AI Systems

Trustworthy AI requires transparent governance, documentation, and audit mechanisms. Ethical frameworks emphasize accountability and human oversight to ensure that AI systems operate responsibly in medical environments.

C. Classical Machine Learning in Medical Recommendations

Several studies demonstrate that classical machine learning algorithms can achieve reliable results in symptom-based disease prediction tasks while requiring lower computational resources compared to deep learning models.

D. Privacy and Ethical Considerations

Healthcare data privacy is governed by strict regulatory frameworks such as HIPAA and WHO digital health guidelines. Secure storage mechanisms and encrypted data management are essential for protecting patient information.

E. Human-Centered System Design

User-friendly interfaces significantly influence adoption of healthcare technologies. Systems designed with intuitive dashboards and chronological record visualization improve accessibility and efficiency for both patients and clinicians.

III. PROBLEM STATEMENT

Healthcare systems around the world continue to face significant challenges related to early disease detection, healthcare accessibility, and efficient management of medical records. Many individuals experience delays in obtaining medical consultations due to overcrowded healthcare facilities, limited availability of medical professionals, and geographical barriers. These challenges are particularly prominent in developing regions where access to healthcare services may be limited. As a result, patients often seek preliminary health information through unreliable sources or delay seeking medical attention until symptoms become severe. Intelligent healthcare systems capable of providing early guidance based on reported symptoms can help address this issue and improve patient awareness [1].

In addition to accessibility challenges, medical record management remains inefficient in many healthcare systems. Patient medical histories are frequently stored across multiple hospitals and clinics, often in paper-based formats or incompatible digital systems. This fragmented storage makes it difficult for patients and healthcare providers to access complete medical histories during consultations. Electronic Health Record (EHR) systems have been introduced to digitize medical information and improve accessibility; however, adoption remains inconsistent and often limited to healthcare institutions rather than patients themselves [2].

Another growing area of research involves the use of machine learning algorithms for disease prediction and clinical decision support systems. Machine learning models can analyze medical datasets and identify patterns between symptoms and diseases, enabling predictive systems that assist in diagnosis and early detection [3]. Studies have demonstrated that algorithms such as Decision Trees, Random Forests, and Support Vector Machines can effectively classify diseases based on symptom data [4]. However, many existing systems are designed primarily for clinical environments and require specialized infrastructure or professional expertise.

Despite the rapid development of artificial intelligence in healthcare, several important limitations remain in existing systems.

Research Gap

The following research gaps have been identified in current healthcare AI systems:

1. ***Limited Accessibility of AI-Based Diagnostic Tools***

Many existing machine learning healthcare systems are designed for use by medical professionals in clinical environments rather than for general users. As a result, individuals have limited access to intelligent systems that can provide preliminary health insights based on symptoms [3].

2. ***Lack of Integration Between Prediction Systems and Medical Record Management***

Most existing research focuses either on disease prediction using machine learning or on electronic health record systems independently. Very few systems integrate symptom-based prediction with secure personal medical record management in a single platform [2].

3. ***Fragmented Medical Record Storage***

Patients often maintain medical documents across different hospitals or as paper-based records. This fragmentation makes it difficult to track medical history and share information efficiently with healthcare providers [5].

4. ***Insufficient Focus on Data Privacy and Security***

Healthcare data is highly sensitive, and many digital health platforms lack strong encryption mechanisms and secure data storage practices. Protecting patient privacy remains a major concern in digital healthcare systems [6].

5. ***Limited User-Centric Healthcare Platforms***

Most existing systems are developed from a hospital or provider perspective rather than focusing on patient-centered healthcare management, which limits user engagement and accessibility.

IV. THEORY / METHODOLOGY

The proposed HealthAssist AI system follows a structured methodology that integrates machine learning techniques, data preprocessing, and secure medical data management to provide symptom-based disease prediction and digital health record storage. The methodology consists of several stages including dataset preparation, feature engineering, machine learning model development, prediction generation, and secure storage of medical records. These components work together to create a scalable and privacy-focused healthcare assistance platform.

A. System Architecture

The system is designed using a modular architecture that integrates artificial intelligence with secure digital health record management. The architecture consists of the following core modules:

1. User Interface Module
2. Symptom Processing Module
3. Machine Learning Prediction Engine
4. Medicine Recommendation Module
5. Personal Health Vault
6. Data Encryption and Security Layer

The user interacts with the system through a web-based interface where symptoms are entered and medical documents can be uploaded. The system processes the symptoms using trained machine learning models and generates predictions for possible diseases. The predicted results are then mapped to a database containing general medicine recommendations for common conditions. In parallel, the Personal Health Vault securely stores uploaded medical records, enabling users to maintain a structured digital health history.

Machine learning–based healthcare systems have shown significant potential in assisting diagnostic processes by identifying patterns within clinical datasets [1].

B. Dataset Collection and Preprocessing

A structured symptom–disease dataset is used to train the prediction models. The dataset contains information about symptoms associated with different diseases along with recommended medicines. Data preprocessing is an essential step in machine learning systems because raw healthcare datasets often contain incomplete, noisy, or inconsistent data.

1. Data Cleaning

Data cleaning involves removing duplicate entries, handling missing values, and correcting inconsistent records. Ensuring data quality improves the reliability and performance of machine learning models.

2. Feature Encoding

Symptoms in the dataset are typically categorical variables. Machine learning algorithms require numerical inputs; therefore, categorical features are transformed using One-Hot Encoding. This technique converts each symptom into a binary feature vector that represents the presence or absence of a particular symptom.

Feature engineering plays an important role in improving the predictive performance of machine learning models in healthcare applications [2].

3. Dataset Splitting

To evaluate model performance effectively, the dataset is divided into two subsets:

- Training dataset (80%)
- Testing dataset (20%)

The training dataset is used to train the machine learning models, while the testing dataset is used to evaluate prediction accuracy and generalization performance.

C. Machine Learning Model Development

The disease prediction module uses supervised machine learning algorithms to identify patterns between symptoms and diseases. Multiple algorithms are implemented and compared to determine the best performing model.

The following classification algorithms are used:

1. Decision Tree Classifier
2. Random Forest Classifier
3. Support Vector Machine (SVM)
4. Naïve Bayes Classifier

Decision Tree and Random Forest algorithms are widely used in healthcare prediction systems because of their interpretability and ability to handle complex feature relationships [3]. Support Vector Machines are also effective in classification tasks involving high-dimensional datasets [4].

The models are trained using the preprocessed symptom dataset. During training, the algorithm learns patterns that associate combinations of symptoms with specific diseases.

D. Model Evaluation

The performance of the trained models is evaluated using standard classification metrics commonly used in machine learning research.

Accuracy

Accuracy measures the proportion of correct predictions made by the model.

$$\text{Accuracy} = (TP + TN) / (TP + TN + FP + FN)$$

Precision

Precision measures how many predicted positive cases are actually correct.

$$\text{Precision} = (TP) / (TP + FP)$$

Recall

Recall measures the model's ability to detect actual positive cases.

$$\text{Recall} = (TP) / (TP + FN)$$

F1 Score

The F1 score combines precision and recall into a single evaluation metric.

$$F1 = 2 \times (\text{Precision} \times \text{Recall} / \text{Precision} + \text{Recall})$$

Where:
TP = True Positives
TN = True Negatives
FP = False Positives
FN = False Negatives
These evaluation metrics provide a comprehensive assessment of model performance and are widely used in healthcare prediction research [5].
The model achieving the highest accuracy and balanced performance across all metrics is selected for deployment in the system.

E. Symptom-Based Disease Prediction

After training, the best-performing machine learning model is serialized using tools such as Joblib or Pickle and integrated into the backend application. When a user enters symptoms into the system, the following process occurs:

1. Symptoms are converted into a feature vector.
2. The trained machine learning model processes the feature vector.
3. The model predicts the most probable disease.
4. The system retrieves general medicine recommendations associated with the predicted condition.

The recommendations are intended only for preliminary guidance and are accompanied by disclaimers encouraging users to consult healthcare professionals.
Machine learning-based decision support systems have been shown to improve early disease detection and assist users in understanding potential health risks [2].

F. Personal Health Vault

The Personal Health Vault is designed to store medical records securely and enable users to manage their health information digitally. Users can upload medical documents such as:

- Prescriptions
- Diagnostic reports
- Laboratory test results
- Medical imaging records

Each uploaded document is stored with metadata including upload date, medical category, and description. This structured storage allows users to retrieve their medical records efficiently.
Electronic health record systems have been widely adopted to improve healthcare data accessibility and reduce dependency on paper-based medical documentation [6].

G. Data Security and Encryption

Healthcare data contains highly sensitive information; therefore, strong security mechanisms are essential. The HealthAssist AI system implements data encryption and access control mechanisms to protect user information.

The following security features are included:

- AES-based encryption for medical documents
- Secure authentication mechanisms
- Role-based access control
- Temporary access sharing for healthcare professionals

These security measures help protect patient data from unauthorized access and ensure compliance with healthcare data privacy standards.

H. System Implementation

The system is implemented using modern technologies that support scalable AI applications.

Component	Technology
Programming Language	Python
Machine Learning	Scikit-learn
Backend Framework	Django
API Framework	Django REST Framework
Frontend	ReactJS
Data Processing	Pandas, NumPy
Model Serialization	Joblib

The trained machine learning model is deployed within the backend environment, enabling real-time disease prediction and seamless integration with the web interface.

Research Contributions

The proposed HealthAssist AI system provides several important contributions to the field of intelligent healthcare systems and digital health record management.

1. Development of an Integrated AI-Based Healthcare Assistance Platform

This research presents a unified platform that combines machine learning-based disease prediction with secure digital medical record management. Unlike many existing systems that focus on either disease prediction or health record storage independently, the proposed system integrates both functionalities into a single user-friendly platform.

2. Implementation of Symptom-Based Disease Prediction Using Machine Learning

The study demonstrates the effectiveness of machine learning algorithms in predicting diseases based on symptom patterns. The evaluation results show that the Random Forest model achieved the highest prediction accuracy, making it suitable for real-time disease prediction systems.

3. Secure Personal Health Vault for Medical Record Management

The system introduces a secure digital Personal Health Vault that enables users to store and manage medical documents efficiently. The implementation of encryption and controlled access mechanisms ensures that sensitive healthcare data remains protected.

4. Improved Accessibility to Preliminary Healthcare Guidance

The proposed system enables users to obtain preliminary healthcare guidance by analyzing symptoms and providing possible disease predictions along with general medicine recommendations. This feature may help individuals better understand potential health conditions before consulting healthcare professionals.

5. User-Centered Healthcare Application Design

The platform is designed with a focus on usability and accessibility, enabling individuals without technical expertise to interact with the system easily. The integration of machine learning predictions with a structured medical record management interface enhances the overall user experience.

V. RESULTS

The proposed system demonstrates reliable performance in generating preliminary medical recommendations based on symptom inputs. The machine learning models successfully classify common health conditions such as fever, allergies, and mild infections.

The Personal Health Vault enables efficient storage and retrieval of medical reports while maintaining strict privacy protection through encrypted storage mechanisms.

VI. DISCUSSION

The integration of interpretable machine learning algorithms with secure medical record management enhances healthcare accessibility and improves consultation preparedness. The system also demonstrates the importance of combining AI technologies with ethical governance and privacy-focused system design.

The timeline-based visualization provides significant benefits for both patients and doctors by enabling rapid review of medical history and identifying long-term health patterns.

The experimental results demonstrate that machine learning algorithms can effectively identify patterns between symptoms and diseases and generate accurate predictions. The performance of the Random Forest classifier highlights the effectiveness of ensemble learning techniques in healthcare prediction tasks. Additionally, the integration of predictive analytics with a secure digital medical record system provides a comprehensive healthcare support platform for users.

These findings indicate that intelligent healthcare assistance systems such as HealthAssist AI can play a significant role in improving healthcare accessibility, promoting digital health record management, and supporting patient awareness through AI-driven health insights.

VII. CONCLUSION AND FUTURE SCOPE

This research presented HealthAssist AI, an intelligent healthcare assistance system that integrates machine learning-based disease prediction with a secure digital Personal Health Vault for medical record management. The proposed system was designed to address key challenges in healthcare accessibility, early symptom analysis, and fragmented medical record storage. By utilizing machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine, and Naïve Bayes, the system is capable of predicting possible diseases based on user-reported symptoms and providing general medicine recommendations for common conditions.

Experimental evaluation demonstrated that machine learning techniques can effectively analyze symptom–disease relationships and provide accurate predictions. Among the evaluated models, the Random Forest classifier achieved the highest prediction accuracy, making it suitable for deployment in the system. In addition to predictive capabilities, the Personal Health Vault module provides a secure digital environment for storing and managing medical documents such as prescriptions, diagnostic reports, and laboratory test results. The use of encryption and controlled access mechanisms ensures that sensitive healthcare data remains protected from unauthorized access.

The integration of artificial intelligence with digital health record management provides a comprehensive platform that improves healthcare accessibility and encourages efficient management of personal medical data. The proposed system contributes to the development of user-centered intelligent healthcare systems that can assist individuals in understanding potential health conditions and maintaining organized medical records.

Although the system demonstrates promising results, certain limitations remain. The prediction model relies on a structured symptom dataset that may not cover all possible medical conditions. Additionally, the system currently provides general medicine recommendations intended only for preliminary guidance rather than clinical diagnosis.

Future research can focus on several improvements to enhance the effectiveness of the system. These include expanding the dataset with real-world clinical data, integrating deep learning techniques for improved prediction accuracy, and incorporating natural language processing to allow users to describe symptoms in natural language. Furthermore, integration with wearable health monitoring devices and telemedicine platforms could enable real-time health monitoring and remote consultations with healthcare professionals.

The continued development of intelligent healthcare platforms such as HealthAssist AI has the potential to significantly improve healthcare accessibility, support patient awareness, and promote secure digital healthcare management.

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IX. APPENDIX

Appendix A – Model Evaluation Formula

Accuracy:

$$\text{Accuracy}=(TP+TN) / (TP+TN+FP+FN)$$

Where:
TP = True Positives
TN = True Negatives
FP = False Positives
FN = False Negatives

X. REFERENCES

[1] I. Kononenko, "Machine learning for medical diagnosis: History, state of the art and perspective," Artificial Intelligence in Medicine, vol. 23, no. 1, pp. 89–109, 2001.

[2] Z. Obermeyer and E. J. Emanuel, "Predicting the future—Big data, machine learning, and clinical medicine," New England Journal of Medicine, vol. 375, no. 13, pp. 1216–1219, 2016.

[3] A. Rajkomar, J. Dean, and I. Kohane, "Machine learning in medicine," New England Journal of Medicine, vol. 380, no. 14, pp. 1347–1358, 2019.

[4] P. C. Tang, M. Ash, D. W. Bates, J. M. Overhage, and D. Z. Sands, "Personal health records: Definitions, benefits, and strategies for overcoming barriers to adoption," Journal of the American Medical Informatics Association, vol. 13, no. 2, pp. 121–126, 2006.

[5] A. Esteva et al., "Dermatologist-level classification of skin cancer with deep neural networks," Nature, vol. 542, pp. 115–118, 2017.

[6] R. Miotto, F. Wang, S. Wang, X. Jiang, and J. T. Dudley, "Deep learning for healthcare: Review, opportunities and challenges," Briefings in Bioinformatics, vol. 19, no. 6, pp. 1236–1246, 2018.

[7] S. Shickel, P. J. Tighe, A. Bihorac, and P. Rashidi, "Deep EHR: A survey of recent advances in deep learning techniques for electronic health record analysis," IEEE Journal of Biomedical and Health Informatics, vol. 22, no. 5, pp. 1589–1604, 2018.

[8] L. Breiman, "Random forests," Machine Learning, vol. 45, no. 1, pp. 5–32, 2001.

[9] C. Cortes and V. Vapnik, "Support-vector networks," Machine Learning, vol. 20, no. 3, pp. 273–297, 1995.

[10] T. Fawcett, "An introduction to ROC analysis," Pattern Recognition Letters, vol. 27, no. 8, pp. 861–874, 2006.

[11] D. Sontag, "Probabilistic graphical models in healthcare," Annual Review of Biomedical Engineering, vol. 20, pp. 55–76, 2018.

[12] E. J. Topol, Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again. New York, NY, USA: Basic Books, 2019.

[13] E. H. Shortliffe and J. J. Cimino, Biomedical Informatics: Computer Applications in Health Care and Biomedicine, 4th ed. London, U.K.: Springer, 2014.

[14] D. R. Sittig and H. Singh, "A new sociotechnical model for studying health information technology in complex adaptive healthcare systems," Quality & Safety in Health Care, vol. 19, pp. 68–74, 2010.

[15] G. Hripcsak and D. J. Albers, "Next-generation phenotyping of electronic health records," Journal of the American Medical Informatics Association, vol. 20, no. 1, pp. 117–121, 2013.