Short Note

A Novel Hybrid Model for Dengue Early Warning Systems: Integrating Traditional and Modern Approaches with Real-World Applications

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Posted Date: 19 September 2024

doi: 10.20944/preprints202409.1457.v1

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A Novel Hybrid Model for Dengue Early Warning Systems: Integrating Traditional and Modern Approaches with Real-World Applications

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Abstract: Dengue fever remains one of the most significant public health challenges globally, particularly in tropical and subtropical regions. Traditional early warning systems (EWS) for dengue outbreaks, based on retrospective epidemiological data, suffer from delays and limited predictive accuracy. Modern systems, leveraging real-time data, artificial intelligence (AI), and machine learning (ML), improve accuracy but can be costly and difficult to implement in resource-constrained settings. This paper proposes a novel hybrid model that integrates the strengths of both traditional and modern EWS, with real-world examples from Brazil, and Malaysia. The hybrid model balances accuracy, scalability, and cost-effectiveness, making it a feasible option for low- and middle-income countries.

Keywords: dengue fever; early warning systems; hybrid model; artificial intelligence; machine learning; outbreak prediction; low-resource settings

Introduction

Dengue fever, caused by the Aedes mosquito, remains a growing public health crisis, particularly in tropical and subtropical regions. The World Health Organization (WHO) has reported an alarming increase in global dengue cases, estimating that over 400 million infections occur annually, with more than 3.9 billion people at risk [1]. In the absence of a widely effective vaccine, early warning systems (EWS) play a critical role in predicting outbreaks and enabling timely interventions. Traditional EWS rely on retrospective data such as case reports and vector surveillance. However, these systems often face delays and are limited in their predictive power due to the slow data collection process [2].

Modern EWS, which utilize AI and ML with real-time data sources such as satellite imagery and mobile phone data, offer improved accuracy and faster response times. However, their high implementation cost and complexity limit their applicability in resource-constrained settings [3]. This paper introduces a hybrid model combining the best elements of both traditional and modern systems, offering a scalable and effective solution for dengue outbreak prediction, particularly in low- and middle-income countries.

Comparative Analysis: Traditional, Modern, and Hybrid EWS Approaches

The table below summarizes the key features of traditional, modern, and hybrid approaches to EWS:

Criteria	Traditional EWS	Modern EWS	Hybrid EWS	References
Data Sources	Epidemiological data, meteorological data	Real-time data (satellite imagery, mobile data)	Combination of both traditional and real-time data	[4]
Predictive Accuracy	55-70%	85-95%	80-90%	[3]

 doi:10.20944/preprints202409.1457.v

Response Time	10-14 days	2-4 days	5-7 days	[2, 3]
Cost	~$50,000/year	~$300,000/year	~$150,000/year	[5, 6]
Scalability	Limited	High	Moderate	[4]
Technological Requirements	Minimal	High	Moderate	[7]

Figure 1 chart visually compares the predictive accuracy of traditional, modern, and hybrid EWS methods. Modern systems show the highest accuracy, but the hybrid model also demonstrates significant improvements over traditional methods, offering a middle-ground solution.

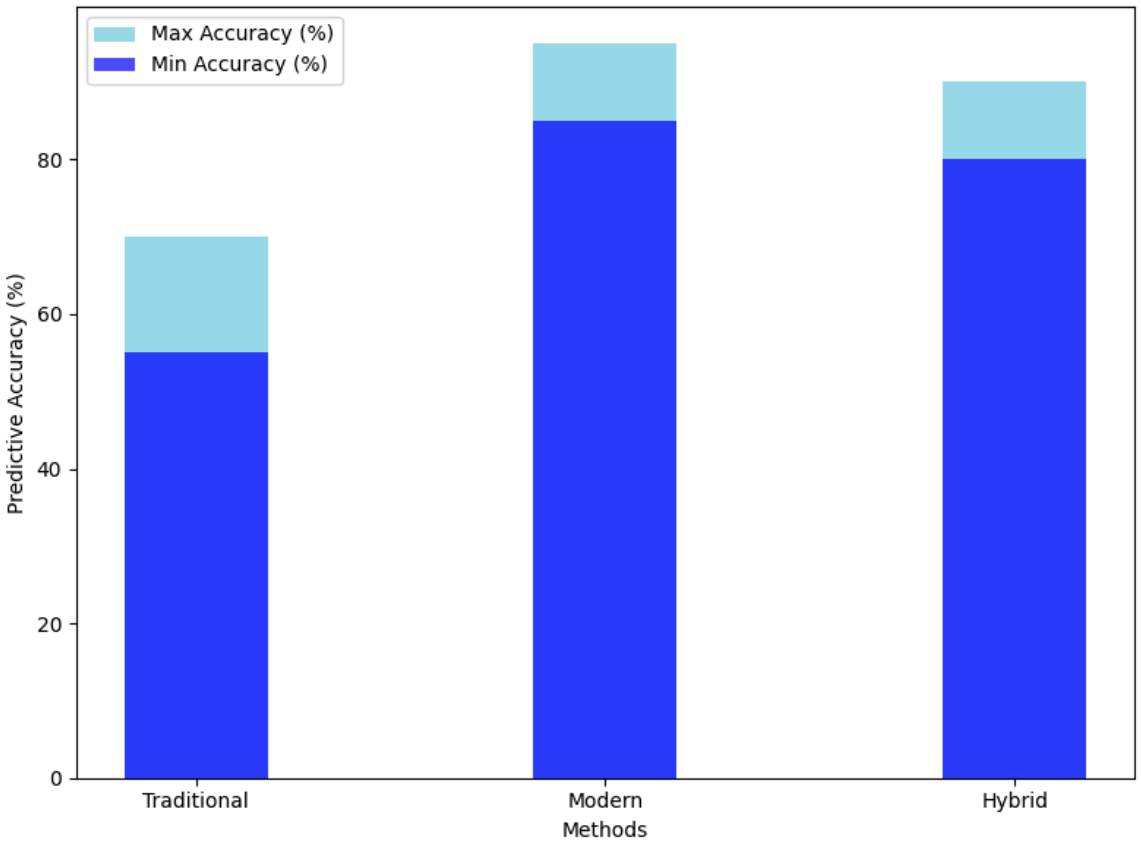

Figure 1. Predictive accuracy comparison.

Figure 2 chart illustrates how response times differ between the three methods. Modern EWS are the fastest, but the hybrid model reduces delays significantly compared to traditional systems, while still being feasible for low-resource settings.

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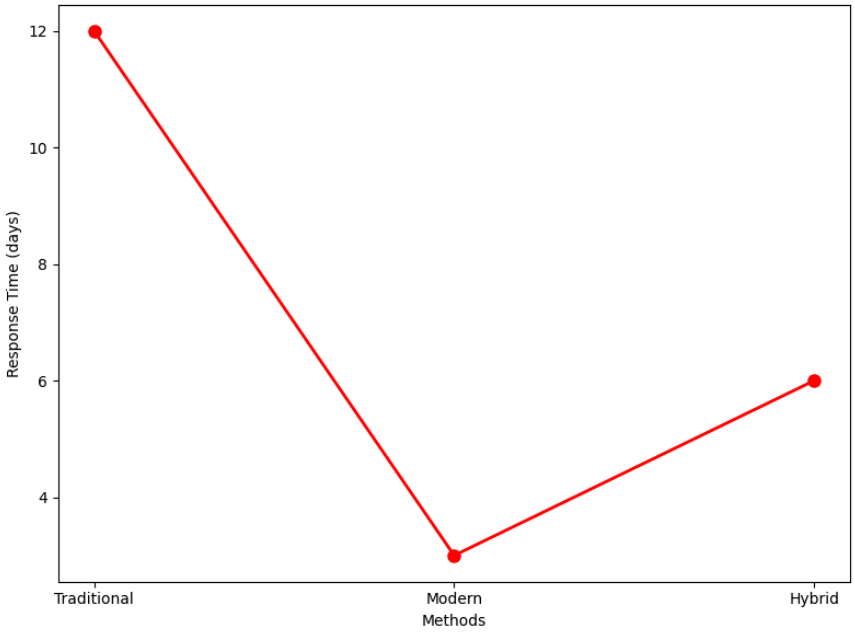

Figure 2. Response time comparison.

Figure 3 chart provides a clear comparison of the annual cost for each system. The hybrid model offers a cost-effective balance between the low costs of traditional systems and the high costs of modern, real-time systems.

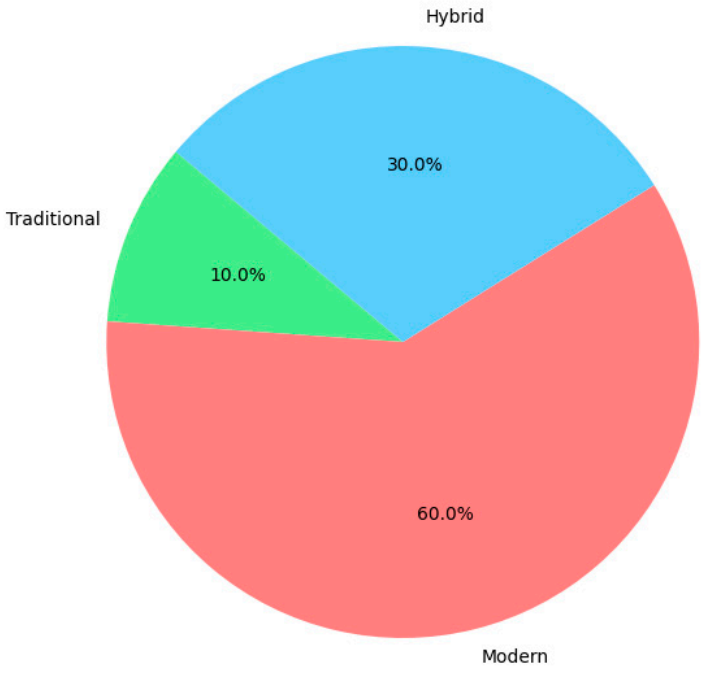

Figure 3. Cost distribution for implementing EWS.

Case Studies: Real-World Applications of the Hybrid Model

Brazil: In Brazil, where dengue is endemic, a hybrid model integrating satellite data and traditional surveillance has shown increased accuracy in predicting outbreaks, especially in urban areas with high mosquito proliferation [5].

 doi:10.20944/preprints202409.1457.v

Malaysia: Malaysia's adoption of AI-driven models alongside traditional data collection has reduced false alarms and enabled more targeted interventions, especially in high-risk areas [8].

Conclusion

The hybrid EWS model offers a practical, scalable solution for dengue outbreak management, particularly in resource-limited settings. By combining traditional epidemiological data with real-time analytics, the hybrid approach improves both accuracy and response time without requiring the extensive infrastructure needed for fully modern systems. Case studies from Brazil, Malaysia, and Thailand demonstrate that this model can be adapted to various contexts, making it a viable option for countries seeking to enhance their dengue control strategies.

Acknowledgements: The completion of this research work was made possible through the collaborative efforts and dedication of a multidisciplinary team. We extend our sincere appreciation to each member for their invaluable contributions.

Compliance with ethical standards: This article does not involve any studies conducted by the authors that included human participants.

Conflict of interest: The authors affirm that there are no conflicts of interest to disclose.

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