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Dengue Disease Forecasting: Current Outbreak and Diagnostic Model's Analysis

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Abstract. The global burden of infectious Dengue disease remains a tricky bomb as its explosion is no longer restricted to tropical/subtropical regions anymore, also the absence of a globally approved vaccine is still there. Continuous research is done to devise systems that could timely predict, diagnose, and treat patients to effectively lessen the yearly Dengue death toll worldwide which resulted in a regular escalation of research in this area. This paper aims to perform a quick effective review of studies done till December 2020, emphasizing forecasting of Dengue epidemiology covering a range of factors such as diagnostics, surveillance, and prognosis prediction so that the intended reader can get an overall scheme of the current research progress well as obstacles regarding Dengue infection. This study points out numerous predictive approaches to Dengue investigation and several open issues which require further investigation eg: human mobility, mosquito breeding sensory reporting, diagnosis of dengue warning stages which may lead to a more accurate and detailed dengue patient prediction and care model. This paper has a good blend of papers encompassing various research directions both traditional and innovative in Dengue epidemiology which are further sub grouped according to their proposed approach and objectives to enhance understanding.

Keywords. Classification approach, Dengue Epidemic, Expert system, Infectious disease epidemiology, Machine learning, Prediction accuracy

1. Introduction

Dengue often known as the Dengue infection is mainly transmitted by the female Aedes aegypti species mosquito which is also responsible for chikungunya, zika, and yellow fever infections. This mosquito is day-biting urban adapted and ovipositors in natural and artificial stagnant water collections [1]. Before 1970, there are only nine countries under the Dengue threat which has now extended to more than 100 countries in WHO regions, 2016 year being marked as a huge Dengue outbreak year worldwide [2]. To date, no globally accepted licensed treatment or vaccine for Dengue is present which further makes preventive measures- the best strategy in the battle against this disease [1]. The sudden changes in world climate have impacted rainfall trends and temperature oscillations, which have a direct influence on water habitat availability. Earlier research has found a link between the transmission of Dengue infection and climatic conditions but the correlation is positive or negative; both are still debatable [3]. However one of the findings that supports the positive correlation is the very distinct epidemic pattern of Indian Dengue infection, as it originates in the south and

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then spreads to the north in a fixed pattern yearly. The mosquitoes breed in warm, humid environments so they are expected to follow the monsoons northwards as this season increases the survival rate of mosquitoes thereby escalating the possibility of transmitting the virus to other people [4]. But the epidemiology of Dengue which used to be constricted to tropical/subtropical areas is no longer valid as areas with extreme colder temperatures have also reported dengue findings. Researchers believe that the mosquito gene responsible for Dengue infection has evolved thereby making itself resilient to colder temperatures [5, 6]. Moreover, recent studies suspect human mobility to be the prime cause of the widespread Dengue disease across the globe as an infected human has more tendencies to travel longer distances over the globe than the Dengue virus-carrying mosquito itself [7, 8, 9]. Data source1: Directorate of National Vector Borne Disease Control Programme, Dte.GHS, Ministry of Health & Family Welfare. Source2: Lok Sabha and Rajya Sabha unstarred questions, Ministry of Health and Family Welfare) shows Cases reported of Dengue are rising at alarming rates each year (2017 being the deadliest Dengue year since 2009) highlighting the dire need to curb this disease outburst on an early basis.

It is speculated that the occurrence of COVID19 has camouflaged Dengue reporting in the year 2020 as both being infectious viral infections cause similar symptomatic onset thereby the former being more deadly overpowered the latter in grabbing the attention of the concerned parties. As discussed earlier, the absence of the Dengue vaccine confines the absolute preventive measure but still, researchers are contributing to finding ways that increase ways that could aid in combating this disease[10]. The novelty of this work is that it doesn't focus only on predominant research directions in Dengue prediction only but also focused on newer approaches which may help existing systems become more resilent against disease fighting. So the motivation can be broadly categorized as follows:

- To emphasize the need to predict Dengue infection effectively and precisely.
- To perform a deep analysis on various aspects of Dengue epidemiology and highlight the key areas of study.
- To study the role of different prediction models in combating Dengue disease.
- To examine the solutions, main challenges, and open issues in the existing literature.

2. RELATED WORK

The section can broadly be subdivided into three parts based upon the nature of the objective proposed/ achieved by researchers in their study; namely Dengue outbreak prediction/control, Dengue diagnostic/prediction, and lastly Dengue vector/human subjectively. The grouping is done by carefully understanding the similarities, differences, and trends which are interpreted in each study.

2.1. DENGUE OUTBREAK

Models working on Dengue outbreak forecasting are predominately using meteorological data along with monthly/ annual Dengue death cases reported according to the concerned geographical location of the intended research [17, 18, 22, 30]. Some key studies are being classified under this section thereby giving a quick view of factors such as dataset, prediction technique, the accuracy of the model, country in which the model is focused along with some key findings of each study. Researchers from Malaysia and Thailand have predominant share in this type of research when compared to other countries. Proposed system using Multivariate Poisson regression model, SARIMA & SARIMA with external regressors for selection, Fuzzy logic , API, SOAP, MongoDB, and NoSQL have been observed best in dengue cases prediction in Malyasia [14,15,17,20]. The results support previous studies-with temperature & humidity being powerful predictors in the magnitude of dengue incidence and also exhibits limitations such as under-reporting, limitation of data, and unmeasured confounders such as population density data, dengue serotypes and herd immunity, access to piped water, effective vector control. It was also found for long-term forecasting, fuzzy is talented in minimizing errors. However if data from weather, social media as well from hospitals can be combined and fed to the system for diverse and better prediction not only on patient symptom level but also on outbreak level with warning generation. Whereas researchers focusing on Thailand preferred CART and C5 algorithm with Equal-Width 4 Binning method, Delay Permutation Entropy with radial basis function in SVM, Fuzzy Association Rule Mining (FARM) which showed a strong correlation between dengue cases and rainfall DPE [13, 16,18,19]. The results were consistent with observations that dengue outbreaks always during the rainy season. Various satellite-based indices such as thermal condition, temperature condition, and greenness of vegetation also appear in the model that complement early detection but it is intended to predict whether or not a high incidence of disease will occur several weeks in the future.The models showed good performance in predicting multi-week dengue incidence 4 weeks in advance. But sudies of India and Vietnam using SMR, SARIMA & Poisson distributed lag model and Zero-inflated Poisson Regression Model have some similar as well as contradictory findings [23,25]. In kolkatta based research it was found that there is an increasing Dengue infection trend observed with the rise in carbon dioxide emission along with a correlation between climatic variables and dengue incidence is observed whereas in Vietnam research findings although this study is in line with previous findings of temperature and relative humidity being significant factors. It strongly negates the effect of cumulative rainfall on dengue incidence.

2.2. DENGUE DIAGNOSTIC

Dengue like any other virus-causing disease exhibits flu-like symptoms which are very often neglected by the suffering human .Here we can classify papers broadly into two zones i.e. machine learning/ AI based or Big data-IoT/ Cloud based. Majorily researchers used machine learning algorithms such as ANN, DT , NB, Fuzzy, LDR, SVM based classifiers along with clinical as well as non-clinical data to predict whether a person is suffering from dengue infection or not [4, 5, 6, 7, 8, 9]. The Non-clinical data contains entries for age, gender, vomit, abdomen pain, chills, body ache, headache, weakness, and fever and Clinical data contains values for platelet count, temperature, heart rate, NS1, IgM, IgG, and Elisa. However it is observed that although among top classifiers Linear discriminant model comes yet it has least impressive sensitivity as well as specificity. Also the uneven distribution often results in biased machine classifications. ANN, fuzzy, and DT are the best classifier for patient based dengue prediction yet most of the studies primarily find only dengue positive and negative and fails to investigate from which level of dengue, the patient is suffering. Moreover For correct diagnosis, both symptoms and clinical test results can only give confirmed results. In some studies researchers used cloud computing, big data and IoT along with the existing classifiers to enhance infected patient detection and among them some were effective for dengue detection at an earlier phase [10, 11, 26].. The population is categorized into 3 main parts of vulnerability: high, mid, and low. The symptomatic investigation is carried out followed by an alert sent to mobile. The severity level is being predicted and it's proposed that patient will get an alert for measures of safety: diet, rest &care. However cost of sensors and malfunctioning of devices to give faulty data are the limitations of this approach.

2.3. DENGUE VECTOR/HOST

Researchers always try to explore various dimensions to find even those parameters which may have some effect either directly/or indirectly on the intended subject. Similarly in Dengue epidemiology, these three studies are analyzed. The proposed system comprises a water storage tank in which single shot multibox detectors are used along with Inception_V2 to identify Aedes Ageypti larvae without raising any false alarm. Training data images of Aedes larvae were tiny, thereby too sparse for better training resulting in the loss of accuracies still, there was no false alarm observed in the test. Although results are satisfactory, more work needs to be done in the detection of smaller objects for better larvae detection. This approach claims to estimate the dengue mosquito population in stagnant water habitats [27]. Whereas in another study system using MOSapp and DISapp will facilitate the working of EWARS by allowing on-field health workers to upload data from surveillance as well as environmental data as well as relevant data uploaded by the community providing Mosquito abundance parameters is proposed for better disease surveillance system. However here conceptual framework is discussed which could be validated by practical implementation in the future [28]. A newer approach was suggested by using modified deterministic model taking into account the assumption that only humans are capable of transmitting Dengue over longer distances to foretell Dengue spread. Past dengue victim records, population data, and human mobility data (obtained from CDR –cell towers) are input parameters to the model to detect only infected human, capable of traveling and spreading dengue over the globe [29].

3. CONCLUSIONS

Vector-borne disease – Dengue has become one such global burden with the death toll being quite high and early detection almost always is confused with viral fever by the common people, making its prediction a more complex task. As discussed in section 2 many experts have studied and proposed systems that gave high accuracies. Though no study has claimed to effectively develop a model which can stand alone detect this infection in a timely and categorize each according to the type of Dengue infection i.e. DF, DHF, and DSS nor they could accurately alert when the disease prognosis into a life-threatening stage. However, after careful analysis of the studies, it can be concluded that a collaborative approach in which not only the outbreak prediction is the main focus but also diagnostics, vector handling, human mobility, IoT/ Machine learning, are also incorporated such that each system works standalone as well as a unit in harmony to achieve the best possible Dengue surveillance system for the mass population. Moreover, it's seen that major work is done in Dengue cases/outbreak prediction whereas patient eccentric prediction systems should be more encouraged. The author came to the conclusion that more work is needed to be done on the patient level, for which machine learning has proved to be effective predictive approach.

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