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The use of Metaheuristic Algorithms in Early Prediction and Forecasting of Flood – A Use of Cuckoo Search Algorithm based Optimization for Flood Controlling

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Abstract*: *Flood is one of the disasters which have multiple impacts on the society and industry. It has severe impacts on the urban economy and has forced the scholars to develop resiliency plans. Various types of flood forecasting techniques developed by the scholars and have certain limitations. There are various types of multiple modeling techniques which are being used for flood controlling and each has certain limitations. The optimization techniques along with the artificial intelligence algorithms can be helpful for monitoring and early prediction of flood. The neural network models promises better accuracy compared to convention models for prediction, but they face great difficulties in selection of appropriate model parameters. In the said context, here an effort has been made to explore the importance of Cuckoo theorem in flood management. The cuckoo search algorithm can be used for parameter tuning. The hybrid approach of using cuckoo search algorithm with neural networks has given far better accuracy compared to standalone algorithms. The use of such Cuckoo Search Metaheuristic algorithm will help us to predict early warning system than any other method and helps us to align the flood controlling activities. The paper presents the used of variants of cuckoo search algorithm for early flood prediction. The paper unfolds major insights of flood scenarios along with the significance of flood control and monitoring.

Keywords: Flood control, Cuckoo Algorithm, Modelling, Optimization

I. INTRODUCTION

As per engineering terminology, flood can be defined as, 'a high stage of flow in a water carrying channels, such as in river, drain or their tributary or in a water retaining body i.e. lake, pond, reservoir, seas, ocean or other low lying areas. It can further be said that, the level at which water over flows over its banks and inundates the adjoining areas.

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Today, because many floodplains are industrialized or populated by residential neighborhoods, the floods are no longer welcomed as bearers of renewal for the environment; rather, they are regarded as disasters instead of beneficial fertilization events. Various factors are responsible for flood, such as heavy rainfall, river-flow and tidal-surge, topography, measure of flood control, and alterations in land counters due to infrastructural activities. Floods in river system are well known to every one due to the past events of floods in river systems of India and very well research work and documentation has been made by various research scholars. Against the same, moderate level of work for urban flooding has been carried out by the research scholars in India [1].

Heavy rainfall and limitations of the capacity to carry water through the drainage systems are mainly responsible for urban flooding. Urban flooding has both economic and social impacts to a great extent and they disturb the routine life of the urban people. It also reduces the mobility of the people and also damages to the urban infrastructure, mainly the roads networks. Urbanization is posing numerous challenges for city administrators, planners and policy makers, of which urban floods are increasingly becoming an important challenge. Urban floods are a result of inadequate or poor maintenance of storm water drains, improper planning, encroachment on drains and water bodies, occupation of low lying areas, modification of catchments, and climate change. The level of raising water in an urban area is according to terrain of the area, in flat terrain the flow speed is low and one can manage the transportation through such urban flooding as the level of flood not reaching towards the danger level [2]. In case of intense rainfall burst, due to flash flooding scenario the urban flooding is difficult to manage.

Past of few years are the witness of extremes of floods in major urban areas across the globe and in India [3]. Scholars have pointed out those major reasons for urban flooding are climate change, unplanned urban development and urban administrative apathy [4] [5]. Urban flooding events across the globe have caused severe damages to the socio-economic life (i.e. post flooding scenario) of the people. Such damages have directed the researchers to focus on the development of disaster management system in the context of the development of sustainable cities and communities as per the Goal 11 of United Nations Sustainable Development Goals – SDGs [5].

History indicates that major human settlements took place in the coastal regions due to the business accessibility. Over a period of time, due to the population growth and urban development, the pressure on coastal line has been increased [5]. Due to the strategic importance of coastal cities from the socio-economic-and-environmental challenges, need of suitable disaster management model has been aroused in urban flooding scenario [5] [6]. The cities which exhibits higher urban growth rate have higher chances of urban flooding and devastated impact of floods have analyzed the integration of the urbanization with flood risk [7][8][9]. Year 2018 is a witness of extremes of flooding situation in India, where 18 states have faced minor to severe floods, mainly in states of north-east region. Kerala and West Bengal have faced disastrously heavy spells of rainfall in short span of time, resulted into flooding [10].

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II. NEED OF FLOOD MONITORING CONTROL

With climate change, urban floods are expected to be more frequent (particularly in tropical regions), there is likely to be longer flooding season and newer areas would experience flooding. Urban flooding has been observed worldwide and it is becoming a regular event in Indian cities too. Urban floods are caused by natural events and anthropogenic activities. In Indian cities flooding is becoming frequent due to both human factors and meteorological factors, with the former factor being more predominant. Some of the issues contributing to urban floods are listed below:

I. **Planning issues:** Increasing population, habitations coming up in low-lying areas, encroachment on drainage channels and immediate upper catchment of hilly urban areas.

II. **Technical issues:** Increased imperviousness leading to increased runoff as compared to drainage capacity, improper waste disposal resulting in clogged drains, high intensity – high load of runoff.

III. **Meteorological issues:** Exacerbated by changing climate, resulting in extreme events, NASA studies indicate that the urban heat island effect also results in increased rainfall over urban areas.

IV. **Policy issues:** Lack of integrated flood control implementing agency

Because of urban development's floodplains are encroached, floodways are obstructed, which resulted into the loss of natural flood storage. A continued development and redevelopment in urban areas results into higher density land uses and high land costs. The proportion of impermeable ground in existing developments is increasing as people build patios and pave over front gardens [7] [8]. Due to urban development, impervious areas such as roads, roofs and paving have been increased, which is a main reason for more runoffs in urban zone of region [6].

Past experiences of urban floods in Major metros like Mumbai have shown the stagnation of water on roads, railway tracks and in few cases even at airports, which are mainly due to the inadequate storm water drainage capacity. Such types of urban floods are major reasons for traffic jams and diversions of traffic resulting in loss of valuable human hours. Due to the urban flooding, the asphalt roads and railway tracks are damaged and need attention to restore them during and after the flooding, which increases the financial burden on urban local bodies. Due to the stagnation of water, potable water also gets polluted due to the mixing, and results into epidemic. During monsoon, due to urban flooding, accidents due to open pits, manholes hidden under accumulated water are very common.

There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Guwahati and Delhi in 2010. A special feature in India is that we have heavy rainfall during monsoons. There are other weather systems also that bring in a lot of rain. Storm surges can also affect coastal cities/ towns. Sudden release or failure to release water from dams can also have severe impact. In addition, the urban heat island effect has resulted in an increase in rainfall over urban areas. Global climate change is resulting in changed weather patterns and increased episodes of high intensity rainfall events occurring in shorter periods of time. Then the threat of sea-level rise is also looming large, threatening all the coastal cities. Cities/towns located on the coast, on river banks, upstream/ downstream of dams, inland cities and in hilly areas can all be affected.

It has been found that, flood control measures are needed to reduce the damages caused by the floods and to overcome the rehabilitation cost of urban population. In the present scenario of urban development, it is essential to Apart from the besides the construction of dams and reservoirs and the improvement of river systems, measures to increase infiltration and to store the excess water in small ponds and retention basins are being promoted. Water apart from being regarded as an economic and social commodity was recognized as an essential convenience calling for cooperation rather than conflict. Absolute control over floods is rarely feasible either physically or economically.

Flood modelling and creating flood inundation maps are essential to understand the possible impacts of floods of a given magnitude and to initiate actions on the ground to minimize the damages. Hydrodynamic modelling plays an important role in obtaining the flood characteristics, i.e., the magnitude, duration and the spatial distribution of flooding.
Progress in hydrodynamic modelling during the last decade has led to considerable improvements in ability to simulate flooding scenarios. Models may be classified depending on how the catchment processes are represented (deterministic or stochastic) or on how the catchment is discretized spatially (lumped or distributed). Routing models that estimate the flood wave propagation along a river channel, have been developed with the continuity, momentum and data driven approaches [11] [12] [13] [14]. Studies on flood frequency analysis, based on statistical models, are in general used for understanding the long-term changes in flood magnitudes and frequencies [15] [16] [17]. Various aspects of floods including the hydrological modelling for floods, climate change impacts assessment, remote sensing and GIS for modelling floods, along with case studies [18].
Changing rainfall patterns, due to both natural and anthropogenic causes, have exacerbated the flooding problem in India. The frequencies, magnitudes and the spatial extent of the floods are known to be increasing in the country. Unfortunately, infrastructure development has lagged behind the economic and population growth, resulting in increasing losses and damages due to floods. Poorly conceived drainage infrastructure, coupled with other problems like encroachments, have significantly contributed to the flood deluge year after year, in the face of increasing rainfall intensities, making flash floods a common occurrence. Capacity to deal with rapid changes - such as increase in in extreme rainfall events and rapid urbanization and the ability to anticipate and adapt to slow changes and trends (population increase, climate change) is very minimal in the country, which poses new challenges for flood management.

III. FLOOD MONITORING AND CONTROL- ON AN AI PRESPECTIVE

The computer software automation and self-learning capabilities of today's AI algorithms is becoming helpful in many disciplines. When we are approaching the computer to perform any task two questions arise that, Can the task be carried out by computer? One we came to know that the first question has affirmative answer, it lead to the second question that, how can the given task be carried out by computer? The most advanced and appropriate answer is computer Models. For the scope of this research article the models are computational models for optimization from the metaheuristic categories of algorithm.
In the last few years more and more metaheuristic algorithms have evolved getting inspire from nature. We can see particle swarm optimization was inspired by fish and bird swarm intelligence where the Firefly algorithms have been inspired by flashing patterns of tropical fireflies. All the biological system evolved from natural selection over the span of million years. All the metaheuristic algorithms seems more powerful tool in solving optimization problems as they imitate the best features from nature. Many of metaheuristic algorithms are used in solving NP-hard category of problems including travelling salesman problem (TSP) [19].
Modern day metaheuristic algorithms can be broadly classified in to two major categories as *Intensification* which always keep their searching around the existing best solutions and choose the best among the available bets. The second category is of *Diversification* which explores the entire search space more effectively looking towards more best possible solutions [19].
From the various studies it has been found that, there are majorly three types of brood parasitism namely intraspecific brood parasitism, Cooperative breeding and nest takeover [19]. In some cases host birds can engage conflict with intruding cuckoos, when the host bird identifies the foreign eggs, they will either throw the eggs away or it will abandon the entire nest. Some cuckoos like *Tapera* evolved in such a way that they can mimic the color and patterns of their eggs with the eggs of host bird species, this ultimately increases the re-productivity in the host nest. In addition to these, timing selection by few cuckoo species is also very impressive, in general ordinary cuckoo eggs hatch earlier than the host eggs. When the first cuckoo chick is hatched, the very first action it takes is of abducing the host eggs out of the nest and this ultimately increases the food share of cuckoo chicks provided by the host bird.

IV. CUCKOO SEARCH OPTIMIZATION

The use of Modified Cuckoo Search (MCS) algorithm with multilayer neural network in order to get prediction of climate change with the help of temperature and ozone data. It has been observed that with certain characteristics of data multilayer neural networks are not effective in association. The functional link neural network has been adopted to overcome the problem of convergence of velocity [22]. The primary function of original Cuckoo Search (CS) algorithm is to replace the finest possible solution in the nest of the host bird, assuming that the cuckoo egg contains a better solution compare the egg of host bird. It has been found that with adequate amount of computation, CS returned the best possible solution. But, to derive the optimal possible solution, the search must traverse the whole region via random walks. These random walks ultimately cost in slow convergence rate. Two modification have been adoptedin the MCSwhich includes the change in the step size of levy flights α, and the addition of exchange of information between the eggs [22]. In the original CS algorithm the α is usually remains constant with value 1. The criticality of the step size shows that, the number of generations increases, when the α decreases for MCS [23]. The neural network is trained with the MCS in order to get the more optimal results by reducing the prediction error and fast convergence rate. The assessment of the prediction has been carried out with Mean Squared Error (MSE), Normalized Mean Squared Error (NMSE), Signal to Noise Ratio (SNR) and CPU time.

The results shows that the MSE of 0.001905 for temperature dataset and 0.000101 for ozone dataset produced for higher order 3 and 5, respectively. For NMSE, the results are slightly improved compared to older networks as 0.000585 and 0.000683 for temperature and ozone dataset, respectively. Even the convergence rate of 27.8524s for temperature dataset and 19.2315s for ozone dataset was recorded, which is comparatively lower than the previous [23].

The work carried out by [21] demonstrates the use of CS and MCS with upgraded version of neural network architectures in order to deliver optimal solution that is prediction here, in less time.

Usually there is a risk of flood in the metro cities and especially to the regions located at down step of the dams. The analysis of increase in water level due to all of a sudden rain fall and prediction of flood has become one a crucial problem. Due to lack of timely availability of data and in many case due to human error many a time human lives came in risk across the globe. With advancement of technology and adoption of novel machine learning models for early prediction of flood can be proven helping hands. The use of CS algorithm in parameter estimation of multi-layer feed forward perceptron has been proposed [24]. They used the original CS algorithm for finding the parameters in the multilayer perceptron. They used a vector representation of data while training the perceptron as the solution generated by CS algorithm is in vector forms. The model Cuckoo Search Multilayer Perceptron (CS-MLP) is used for 7 hours early prediction of water level in Ping River at the downtown area of Chiang Mai, Thailand. The river is having the basin size of 44,688 sq. km with a length of 658 km. The average discharge of Ping River is around 9,400 cu ft/s and it will reach to 81,300 cu ft/s at its maximum [25]. This is how it has become crucial for early prediction of water level. Author suggested the entire neural network based prediction model with 26 dimensions and to make the entire solution simple, the fitness value has been calculate using fitness function with the help of Mean Absolute Error (MAE) [25]. It is obvious that, lower the MAE is the better prediction can be achieved.

The data prepared with the collection of 7 different crucial flooding events during the years 2005 and 2006.

The experiment results shows that the MLP with the help of cuckoo search for effective parameter estimation has given promising MAE of 8.971 cm on validation data with 4 input weights, 2 hidden units and one predictor output neuron.

The flood water level forecasting is an important work for decision making for controlling the flood. Even the determination of flood water level is the key for the numerical simulation of river channel. It demands timely and accurate flood monitoring and analysis, during the flood control decision making [26].In the span of more than fifty years hydrological experts developed number of forecasting techniques. Many improvements of the flood forecasting methods adopted the use of novel computational techniques. One of those techniques is Artificial Neural Networks or ANN. Basically ANN is biological nervous system inspired complex mathematical model that understand the association of data over number of iterations. It is a well-known fact that, ANN is able to change its structure based on the internal and externally provided input signals. This characteristics of the ANN make it adaptive systems.

Generally the neural network learns the association between the provided input and output, which is known supervised type of learning. While learning the association, neural networks are dependent on certain criteria called parameters and hyperparameters. That includes parameters as the distribution of a variable, initial weights of network, coefficients in case of prediction and hyperparameters as number of hidden layers, number of units in each hidden layer and type of activation functions to be used. As these parameters plays a critical role in providing association between data in network, the proper selection is very much essential and is open topic of research yet. However, in certain problems the tuning of these parameters becomes more crucial and difficult too. The metheuristic algorithms have provides a reasonably good solution on lower computation cost [27] [28]. The cuckoo search algorithm with its variants, emerged with the novel and effective approach that shown quality results with other computational models.

V. CONCLUSION

Hydrological reports show the criticality of flood monitoring and analysis. The early prediction of flood can be proven very much helpful in order to take the necessary steps from controlling the flood to taking precautionary measures as disaster management. Urban flooding have posed serious threats to the socio-economic structure of the city and its near by industrial activities. Many of the conventional statistical methods have been adopted for monitoring and analysis of the flood. Compare to the usage of such conventional statistical techniques, use of such metaheuristic cukoo search algorithms can be benefited to the decision makers of urban local bodies for promptly initiating action to minimize the socio-economic damage to the city. The available literature shows that these metaheuristic algorithms based methods have been used for early prediction as well. However, the methods are strictly dependent of the variables of the case, as well as many of the other human assumptions. One of the dominating field of computer science, artificial intelligence is having potential to make the association between known data with the results. Neural networks with Optimizationis having potential to meet the quality prediction rate in case of early flood prediction. Under meta-heuristic categories of algorithms cuckoo search techniques is having potential to deliver more accurate results, specifically for the tuning of neural network parameters. Few works has been carried out and shown quality results for early prediction of flood. With the larger size of data set showing previous flood scenarios can lead to more promising results. Here an attempt has been made to show the utility and importance of this Cuckoo Search Algorithm for deriving optimization in Flood Controlling. There is a scope of further work to use this theorem with real time data of any city and mitigating strategies development for disaster management.

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