Flood Alarm

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Abstract- A flood alarm is a non-structural measure for flood forecasting and mitigation. Flood alarm is a neccesary warning method for villages, dam areas, populated areas. It will save a huge mass of land, property & lives from getting destroyed. Several parameters are responsible for flood related disasters and a quick-responding flood alarm system is required for effective flood mitigation measures.

Index Terms- Dam, Flood, Fuzzy, Network, Rainfall, Rise in level of water, River**,**

1 INTRODUCTION

A flood alarm system is a non-structural measure for flood mitigation. Several parameters are responsible for flood related disasters and a quick-responding flood alarm system is required for effective flood mitigation measures. Flood alarm is closely linked to the task of flood forecasting. The distinction between the two is that the outcome of flood forecasting is a set of forecast time-profiles of channel flows or river levels at various locations, while "flood alarm or warning" is the task of making use of these forecasts to make decisions about whether warnings of floods should be issued to the general public or whether previous warnings should be rescinded or retracted [18]. Most of these parameters are atmospheric attributes, which ultimately control the spatial and temporal distribution of rainfall in a given river basin. However, a micro level study on flood hazard in any river basin shows that it is invariably influenced by a number of factors and are broadly categorized into three basic groups, viz., atmospheric, Morphometric and Hydrologic (Chorley et al. [5]). Out of these various factors or attributes, only a selected number of attributes are found to be dominating in controlling flood in a river basin or dam and are varying from basin to basin. Hence, in this paper an attempt has been made to develop the framework of a new model for flood assessment, which take into account of some selected parameters in the form of a 'network model'. Such a model will provide a dam-framed 'vision', and is a critical early step in effective river improvements. It can overcome the limitations of the traditional engineering techniques of river improvements like river channelization, embankments and reservoirs, which are generally applied in a piecemeal manner over relatively short reaches of river without a sound understanding of the broader spatial context (Harper [6]; Brouwer and Van [2]). Since Zadeh [17] published the fuzzy set theory as an extension of classic set theory, it has been widely used in many fields of application, such as pattern recognition, data analysis, system control and flood prediction [3,7,8,9,10,11,12,13,14,15,16].

2 NETWORK MODEL CONSTRUCTION

A network is based on linkages within the systems. A network N is a weakly connected simple digraph in which every arc a of N has been assigned a non-negative integer c(a) , called the capacity of a . A vertex of a network N is called a source if it has indegree 0 while a vertex is called a sink if it has outdegree 0. Any other vertex of N is called an intermediate vertex.

Network models have been developed more recently in the field of flood prediction modeling and their international usage is not as common. Network models can be used to simulate the water storage characteristics of a river by distributing the storage effects through the dam and reservoirs. The distributed nature of a storage is represented by a series of concentrated storages strategically located on the drainage network.

In order to develop a network model for a river, the various attributes of the basin like atmospheric, morphometric and hydrological vis-à-vis annual rainfall pattern will be taken into consideration. This study will enable us to identify the river channel risk from drought during low-flow periods and flood during high-flow periods as well as the potential for water diversion can be articulated in detail. On the basis of the above investigations, a network with "nodes" and "arcs" could be designed for a river basin to relieve drought hazard and flood risk respectively. There are many atmospheric, morphometric (terrain) and hydrological parameters relating to flood. Each node in a network model is represented as a parameter. The relationship between two nodes is called an arc. It is possible that the number of arcs increases with increase in nodes, ultimately give rise to a complex network with a number of possible flow paths for a given basin. Out of these flow paths, only few of them will be responsible for flood in a given river. The effective energy can be determined for all possible flow paths in the basin.

Subsequently, the path in the graph theory was applied to optimize the low or high flow network in the basin by searching for the flood path. By analyzing the high flow network and annual rainfall pattern for a basin, the flood can be estimated. The model generated can be considered as a universal model and is applicable to almost all rivers in the real world. The theoretical aspects of the network model is as follows.

A directed graph G_d is a pair of (V ,E) , where V is a set of nodes and E a set of ordered pairs (v_i ,v_j) called as the directed arcs. The v_i and v_j are initial and terminal nodes respectively (Chen [4]). If each arcs of d G is associated with one or more real numbers, then the directed graph can be termed as weighted directed graph. A network is typical class of directed graph and we define as follows:

N = (V ,E,W) , where V={v_1,v_2,…..v_n } is a set of n nodes, E is a set of arcs, and W is a set of real numbers called the weights of arcs. In the above network N ,

P (u,v) is a path consists of a group of arcs series say {e_1,….e_n}. The weight of the path is the sum of weights of all arcs. The optimal path between the arcs u and v is defined as the path with the minimum or maximum weight among all the paths between these two arcs.

2.1. Identification of Parameters

In a riverine system, the flood is controlled by many important parameters. These parameters are broadly categorized into three groups, viz., atmospheric, morphometric(terrain) and hydrologic parameters.

2.1.1. Atmospheric parameters

The important atmospheric parameters include atmospheric pressure, atmospheric temperature, wind (speed and direction), relative humidity and precipitation (rainfall). Atmospheric pressure and temperature are the normal temperature and pressure near to the surface of the earth. Wind indicates the horizontal flow of air and its direction and velocity can be measured. Relative humidity is the expression of water vapour content of the atmosphere and is defined as the percent ratio of the amount of moisture in a given space to the amount which that volume could contain if it were saturated. Rainfall indicates the water in liquid or solid form that reaches the earth.

2.1.2. Morphometric (terrain) parameters

The significant morphometric parameters in a river basin include basin area, elongation ratio, relief, slope of the basin, lithology, drainage pattern, drainage density, stream frequency, drainage texture, vegetation (type and density), runoff, infiltration capacity, evapotranspiration and overland flow. Basin area (B_a) is the area on a land surface which provides water and sediment to a river. It is usually measured in square kilometer. Elongation ration (R_e) is a measure of basin shape. It is dA/ LB , where dA is the diameter of the circle of area A and LB is the overall maximum basin length measured from the mouth of the river. Relief (H) of a basin is the elevation difference between high and low points. It is an index of the potential energy available in the drainage basin. The greater the relief, greater the erosional forces acting on the basin. The term slope has two commonly used meanings in geographical terms, one referring to the angle of inclination of the surface, expressed in degrees inclined surface is frequently referred to as a hillslope or a valleyside slope and the inclination of that slope is referred to as the slope angle or slope. The slope is categorized into high slope (S_h), medium slope (S_m) and low slope (S_l).

Lithology refers to the distribution of rock types in a basin. The rocks can be hard rocks (R_h) (eg., granite) or soft rocks (R_s) (eg., sandstone). Drainage pattern refers to the spatial orientation of a main stream and its tributaries as seen from an air platform. There are different types of pattern which include dendritic, rectangular, trellised, annular, etc. Drainage density (D) refers to the average stream channel length per unit area. It is L_c/A, where L_c is the total length of the channel system within a basin and

(B_a) is the basin area. Stream frequency (F) is the number of stream segments of all orders pre unit area. Drainage texture is used in association with drainage pattern and indicates the internal drainage and surface runoff of the soil. Vegetation refers to the all types of flora and their distribution in a river basin.

Runoff is the flow of water through hillslopes in the form of baseflow and quickflow.

Infiltration capacity is the maximum rate at which a given soil in a specified condition can absorb rainfall. Infiltration capacity varies with vegetation and litter cover, soil permeability and existing soil moisture content, variations in the last causing a decrease of infiltration capacity during individual storms to a limited value. The amount of overland flow is commonly determined as the excess of surface water remaining after infiltration into the soil has occurred. Overland flow is, therefore, greater on surfaces with lower infiltration capacities and may reach velocities of 180-270m/h. Overland flow may be either unsaturated where rainfall intensity exceeds the surface infiltration capacity plus evaporation and depression storage or saturated when the underlying soil layers are saturated as is common in concavities, near channels and at stream heads after prolonged rain. Overland flow or surface runoff will occur only on the rate at which water supplied to the slope exceeds the infiltration capacity of the soil, which is the maximum rate at which water can enter the soil. Evapo-transpiration refers to the total loss of water from the surface in the form of evaporation from water bodies, soil and transpiration from the vegetation.

2.1.3. Hydrological parameters

The prominent hydrological parameters include channel pattern, channel width, channel depth, channel stability, channel gradient, channel velocity, base flow and channel discharge. Channel pattern usually described as being straight, meandering, braided, etc.. width and depth are the dimensions of the channel. Channel stability refers to the strength of the sediments forming the bed and bank of the channel with respect to the strength of the flowing water in the channel. It can be stable or unstable channel. Channel gradient refers to the slope or gradient of the channel in a river basin. Channel velocity is the average velocity at which water flows in a channel. Figure 1 indicates in a very simple way the characteristic of a drainage basin contains different river channels and tributaries.

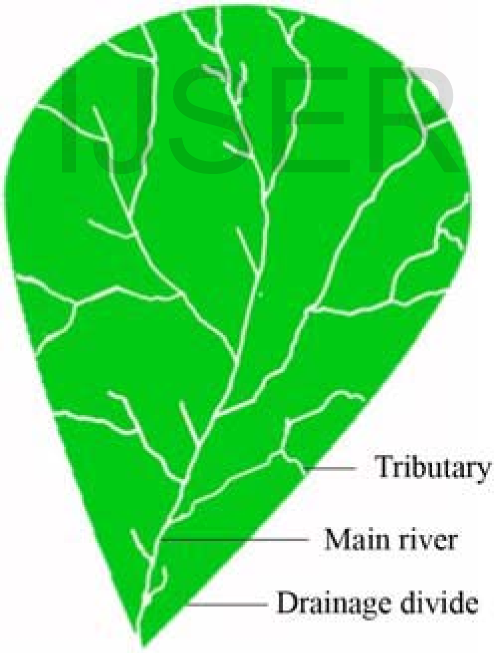


Fig.1. Drainage Basin Concept

Base flow refers to the portion of water in a stream channel that is derived from reservoirs. Channel discharge is the amount of water flowing through a cross sectional areas of the river for a unit time. Out of the above parameters, only some parameters were selected for the flood risk estimation in a river. Among the atmospheric parameters, since all the above mentioned parameters ultimately control the distribution of rainfall in a basin, rainfall (R_f) is selected as the lone parameter in estimating flood. Among the morphological parameters of the basin, the parameters like basin area, slope, lithology, vegetation, infiltration capacity and gradient were selected for the flood estimation. In hydrological attributes, channel width, depth, velocity, cross-sectional area, channel discharge were selected.

2.2. Formation of the network

While constructing the network model for flood estimation, rainfall (R_f) is considered as an independent variable and is taken as the starting node (node with indegree 0), followed by basin area (B_a). This is followed by slope (S) of the basin, which is divided into high (s_h), medium (S_m) and low slope (S_l) based on the variation in the angle of slope. Then comes the lithology of the basin which is broadly divided into hard rock (R_h) and soft rock (R_s).

The fourth set in the network is the vegetation (type and density) and is divided into low (V_l), medium (V_m) and high vegetation (V_h). The fifth set deals with infiltration capacity of the terrain and is divided into low (I_l), medium (I_m) and high infiltration (I_h) capacity. The sixth set is gradient and is divided into high (G_h) , medium (G_m) and low (G_l).

This is flowed by the hydrological variables like channel width (Cw), channel depth (C_d), channel velocity (Cv) and finally these variables control channel cross section area (Ccs). Each flow path from f R to (Ccs) will pass atleast one of the vertex (Cw) or (C_d) or (Cv). The ending node is channel discharge (Cds) (node with outdegree 0), which is the amount of water flowing through the cross sectional area of the river for a unit time. The corresponding network to estimate rive flood is depicted in Figure 2.

2.3. Identification of flow paths

When rainfall occur in a given river basin, some initial abstraction will occur by the soil and vegetation and the amount of water reaching at any river reaches in the basin is controlled by a serial combination of above mentioned variables. Considering the various combination of variables, a complex network with a series of flow paths have been identified. In this model, a total of 38 prominent flow paths (irrespective of channel width, channel depth, channel velocity) have been recognized. This is a universal network model and for a given basin, depending upon the nature of above variables, many flow paths will be formed and one or more will be a maximum or high flow path(s) .

The reliability of the output of this network depends upon the duration of rainfall in a basin. For short spells of rain, the initial abstraction of water will be higher and there by reducing the reliability. However, for long spells of rain covering several hours its reliability is high. Thus, for a given river basin, the rainfall can be measured and based on the above flow path the corresponding amount of surface water reaching at a given reaches in the river can be estimated. This is the river discharge data at that river reaches and when this discharge exceeds the capacity of the river channel (i.e., maximum volume of water that can be accumulated based on the cross sectional area of the channel) at that river reaches will lead to flood.

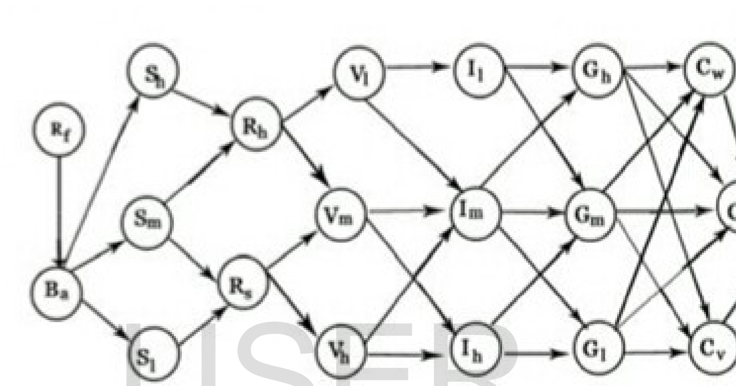


Fig.2.

Network flow from Rainfall (Rf) to Channel discharge (Cdis) for flood prediction.

Ba : Basin area; Sh, Sm, Sl : High, Medium, Low slopes; Rh, Rs : Hard, Soft rocks;

Vl, Vm, Vh : Low, Medium, High vegetation; Il, Im, Ih : Low, Medium, High infiltrations;

Gh, Gm, Gl : High, Medium, Low gradients; Cw, Cd, Cv, Ccs : Channel width, depth, velocity,
cross section.

2.4. Methodology

For each proposed flow path, the quantity of rain water (in percentage) that can reach at a given reaches in the river basin is calculated by proper computation techniques. For that we introduce the following concepts.

Definition 1 [1]. Let E be a fixed set. An intuitionistic fuzzy set in E is an object having the form

$$A=\{<x,\mu A(x),vA(x)>|x\epsilon E\}$$

where, the function $\mu:E\rightarrow[0,1]$ and $vA:E\rightarrow[0,1]$ define the degree of membership and non-membership respectively of the element x to the set A. $0\leq\mu(x)+vA(x)\leq 1$, $\pi A(x)=1-\mu A(x)-vA(x)$ is called the indeterministic part for x . Clearly $0\leq\pi A(x)\leq 1$.

Definition 2. A network N is said to be a fuzzy network if there exists a membership function $\mu vi:VN\rightarrow[0,1]$ such that $0\leq\mu vi\leq 1$. Each node i v is called a fuzzy node.
A fuzzy network N is said to be an intuitionistic fuzzy network if its node i v contains three compartments say, (μvi (x), $vvi(x)$, $\pi A(x)$), where $\mu vi(x)$, $vvi(x)$, $\pi vi(x)$ are respectively called membership, non-membership and indeterministic grades.
Also $0\leq\mu vi(x)\leq$, $0\leq vvi(x)\leq 1$, $0\leq\pi vi(x)\leq 1$, $\pi vi(x)=1-\mu vi(x)-vvi(x)$. If all the nodes in a fuzzy network has an intuitionistic fuzzy node satisfying the above condition, then the fuzzy network is called an intuitionistic fuzzy network.

Definition 3. Let V ={v1, v2,….., vn be the nodes of an intuitionistic fuzzy network and $n<\infty$. The informational energy of an intuitionistic fuzzy node vi is denoted by Ie(vi) and is defined as
$Ie(vi)=\mu vi2(x)+vvi2(x)+\pi vi2(x)$.

Definition 4. The arc of intuitionistic fuzzy network is called an intuitionistic fuzzy arc. If that arc is associated with a real number, then the arc is known as weighted intuitionistic fuzzy arc and the real number is called weight of the arc.

Definition 5. Let $V = \{v_1, v_2, \ldots\ldots, v_n\}$ be the nodes of an intuitionistic fuzzy network and $n < \infty$ Then effective energy of an intuitionistic fuzzy nodes from v_i to v_j ,$i \neq j$ (provided if there is an arc from vi to vj) is denoted by Ee(vi, vj) and is defined as $Ee(vi, v)j = (\mu vi(xi)*\mu(xi) + vvi(xi)*vvi(xi)+\pi vi(xi)*\pi vi(xi))/[Ie(vi)*Ie(vj)]2$ provided $Ie(vi\ ), Ie(vj\ ) \neq 0$, where the operation * means the ordinary multiplication.

Definition 6. The quantity of water that reaches the given observation point of the river channel through the fuzzy network model is defined as

in Qin = Qexpt *Fpi

where the flood prone index Fpi should indicate the abstraction of water by the components of the river channel through fuzzy network.

Definition 7. If V_c be the capacity or the maximum volume of the water that can be accommodated in a given cross-section area of an observation point in the river channel and Ve be the existing water, then Qin be the quantity of water that can be further accommodated in a given observation point before reaching flood. Then, the flood equation can be defined as

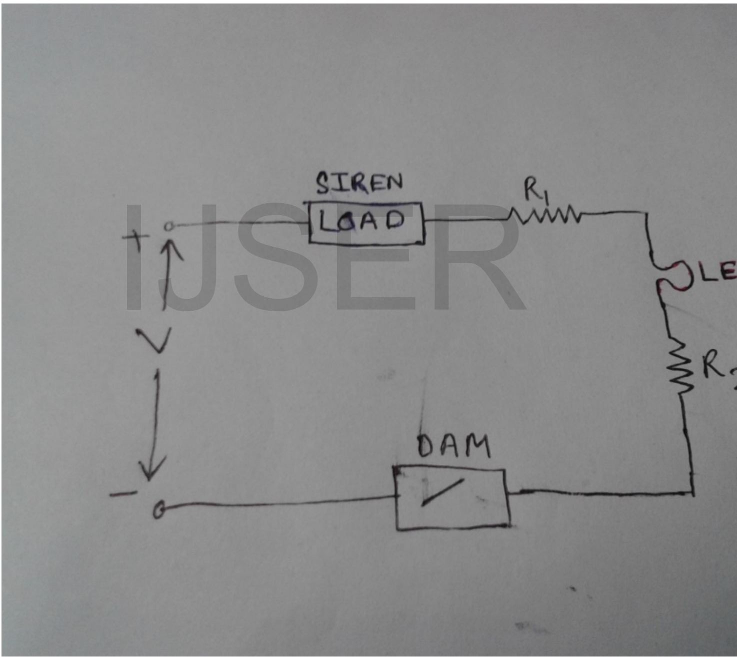
Ve = Ve +Qin

Definition 8. The flood fluctuation index of an observation point in a given river channel is denoted by i F and is defined as

$FI=(1-Ve/Vc)*100, 0\leq Fi<100.$

Remark 1. The Minimum value of the flood fluctuation indices i F of the river channel is taken as the threshold index Tv .

3. CIRCUIT DIAGRAM



4. RESULT

The parameters Vc ,Ve , in Q may be different for different observation points in a given river channel. The c V and e V for a given observation point are measured by field check. From the available data (atmospheric, terrain and hydrological parameters in the
network) of the observation point of a river channel, the Effective energy (Ee), Mean effective energy (Me), Flood prone index pi F , quantity of water theoretically expected exp t Q , quantity of water reaching the observation point as runoff in Q can be calculated.
in Q is calculated from Qexp t through fuzzy network. If (Qin + Ve) exceeds c V , then flood will occur in the given observation point of a river basin. For any given river basin there may be one or more observation points. Whatever may be the case ( ) in e c Q + V > V
for at least one observation point in a given river basin, then flood will occur and that area will susceptible to flood. If there are more than one river channel, and if the pi F of the different river channel is greater than the threshold index v T , then flood will occur in all the given river channels. The same methodology can also be applied in the case of a river basin.

5. CONCLUSION

The fuzzy network (FN) model approach presented for flood warning system
furnishes very promising results and possibilities. Twenty one parameters were analyzed
and membership, non-membership grades were given to each parameter. Atmospheric
parameters were gathered from IMD , Pune and Terrain parameters were derived from
survey of India toposheets (Scale=1:50,000). A part of the hydrologic parameters were

collected by field checks. The possible flow paths, mean effective energy ( ) e M and flood prone index ( ) pi F were estimated,.

The output generated using JSP identifies that the finding is consistent with observed data. Greater accuracy could be obtained by the inclusion of additional parameters such as roads, embankments, railroads etc., that stand in the way of flood dissipation. More substantial improvement certainly should be pursued through further research to improve the Fuzzy network model at greater lead times.

6. ACKNOWLEDGMENT

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