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A fuzzy soft flood alarm model

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Abstract

A wide range of hydrological analyses for flood, water resources, water quality, ecological studies, etc., require reliable quantification of rainfall inputs. This work illustrates a fuzzy analysis that has the capability to simulate the unknown relations between a set of meteorological and hydrological parameters. A fuzzy approach to flood alarm prediction based on the fuzzy soft set theory is applied to five selected sites of Kerala, India to predict potential flood.

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1. Introduction

Rainfall being the dominant component in most hydrological systems, reliable quantification of rainfall is absolutely essential for various ecological, meteorological, geo-morphological and disaster management studies. Since the occurrence and distribution of rainfall over a region is controlled by many independent factors, reliable forecasting becomes a complex exercise. A challenging task for catchment management and flood management in particular is the creation of a reliable quantitative rainfall forecast. Accurate forecasts of the spatial and temporal distribution of rainfall are useful for flood warning. A flood warning system for fast responding catchments may require a rainfall forecast to provide sufficient lead time for early warning.

A flood warning system is a non-structural measure for flood mitigation. Several parameters are responsible for flood related disasters and a quick-responding flood warning system is required for effective flood mitigation measures. Major atmospheric parameters affecting floods are rainfall, wind speed, wind direction, relative humidity and surface pressure. River and topography are two geographical parameters that directly impact rainfall and water dissipation. This paper investigates the potential of fuzzy soft set theory in real-time flood warning. Molodtsov [6] initiated the concept of soft set theory as a new mathematical tool for dealing with uncertainties. Soft set theory has rich potential for applications in several directions, a few of which had been shown by Molodtsov [6] in his pioneer work. In the present paper we use fuzzy soft sets, establish some results on them and develop an algorithm followed by simulation for flood warning in five important locations in the state of Kerala, India.

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2. Fuzzy approach to decision making

The thought process involved in the act of decision making is a complex array of streaming possibilities in which a person selects of discards information made available from diverse sources. In doing so he is led by a meaningful analysis of available information and optimal selection out of several apparently equi-efficient decisions. Information is available on the basis of some criteria and the criterion-values are not crisp but fuzzy sets. In real life situations the information available to a person would be blurred, indistinct, vague and often ambiguous. Examples of such bits of information regarding atmospheric conditions would sound like: high surface temperature, heavy downpour, mild wind and high humidity. Due to the presence of diverse uncertainties it would be impossible to make accurate predictions following classical models which require exact and crisp information.

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 and system control [1,3,5,9,15]. The unique characteristic of this theory, in contrast to classic mathematics, is its operation on various membership functions (MF) instead of the crisp real values of the variables. This heuristic permits fuzzy theory to be a powerful tool whenever it handles imprecise data or ambiguous non-linear relationship between the variables. This theory is extremely effective in handling dynamic, non-linear and noisy data, especially when the underlying physical relationships are not fully understood. As hydrologists are still uncertain about many aspects of the physical processes in the watershed, fuzzy theory proves to be a very attractive tool enabling them to investigate these areas. The past decade has witnessed a few applications of fuzzy logic approach to flood prediction studies [2,7,8,10–14,16,18].

3. Model construction

Definition 1. [6]: Let U be an initial universe set and E be a set of parameters (real-valued variables). Let $P(U)$ denote the power set of U and $A \subset E$. A pair (F, A) is called a soft set over U, where F is a mapping given by $F : A \to P(U)$.

Example 1. Let the initial universe $U = \{L_1, L_2, L_3, L_4, L_5\}$ be the five selected locations in Kerala, viz., Trivandrum, Alappuzha, Cochin AP (Airport), Palakkad and Kozhikode and $E = \{P_1, P_2, P_3, P_4\}$ be the atmospheric parameters, where P_1, P_2, P_3, P_4 are wind speed, wind direction, relative humidity and surface pressure respectively. Suppose that

$$F(P_1) = \{L_1, L_2, L_4\},$$
$$F(P_2) = \{L_3, L_5\},$$
$$F(P_3) = \{L_1, L_2, L_3\},$$
$$F(P_4) = \{L_2, L_3, L_5\}.$$

Each approximation has two parts
(i) a predicate p;
(ii) an approximate value set.
Consider $F(P_1)$, here predicate name is wind speed and value set is $\{L_1, L_2, L_4\}$ (Table 1).

Table 1
Tabular representation of a soft set.

U	Wind speed	Wind direction	Relative humidity	Surface pressure
L_1	1	0	1	0
L_2	1	0	1	1
L_3	0	1	1	1
L_4	1	0	0	0
L_5	0	1	0	1

Definition 2. [4]: Let U be an initial universe set and E be a set of parameters (real-valued variables). Let $P(U)$ denote the set of all fuzzy sets of U and $A \subset E$. A pair (F, A) is called a fuzzy soft set over U, where F is a mapping given by $F : A \to P(U)$.