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Fuzzy Modeling of Water Flow on Lower Indus River Basin Using a New Defuzzification Method Based on Soft Computing

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Abstract: There are many physical systems where linguistic descriptions (Fuzzy Sets) allow better assessments because analyses of real systems are familiar with fuzziness for instance we cannot measure the stream flow accurately because of the fluctuations. A feature of fuzzy system is that it gives an efficient base for measure uncertainty. The analysis of precipitation in Pakistan plays a major part in water flow of Indus basin. Therefore, it is of the fundamental nature to store up its water and utilize it economically. The scientific approach to get this preservation is to build up the stream flow forecasting model. This study here proposes a data-driven algorithm of fuzzy model build on a new parameterized defuzzification method, called Mid Variation Method (MVM), with fuzzy time series that integrates a soft computing technique, termed as Particle Swarm Optimization (PSO). The performance of the algorithm of both training and testing phases are evaluated with adequate estimates of accuracy and less than one errors measurement which exhibit the suitability of the fuzzy model. This paper also presents the adequacy of the proposed model for extreme events and the numerical results exhibit this proficiency over the evaluations of Low Flow Error Criteria (LFEC) and Peak Flow Error Criteria (PFEC) for both seasons of Low and High water flows on average of 0.23% error which do better for fuzzy model adequacy; similarly, there is no Low Flows observations and sufficient accuracy for High Flows in testing phase. The other aspect of this paper is that it provides a major preference if only the observations of water flow s are obtainable, which can be useful for water reserve planners as well as Sukkur Barrage monitoring operators.

Keywords: Fuzzy sets. Indus river, Stream flow, Particle swarm optimization, Irrigation system

1. INTRODUCTION

Pakistan is located between latitudes (23 degree and 35 minute) north to (37 degree and 05 minute) north and extends from longitudes (61 degree) east to (76 degree) east. River provides an attraction for humane settlement and economic development. It is apparent that there are three types of phenomenon that a river does. It attires away its banks and bed; this is erosion. It carries the material brought into it by rain or by its own erosive action; this is transport. It drops this material, sometimes on its own bed, sometimes in a lake, sometimes in the sea, but always at a lower level than the point at which the material was received; this is deposition. As far as the form of the land is considered, the erosive act is on the whole the most important, but the erosion depends to a large extent upon the material transported, and transport and erosion cannot be considered altogether independently.

Water is a natural resource. The water that reaches from the atmosphere to the earth is distributed in various ways: rain, snow and hail. Some of water runs off the earth's surface as river and streams, draining into lakes and the sea. The rest of it is either utilized by plants or soaks into the ground. Water is returned to atmosphere as water vapour through from surface water and by transpiration from plants. Rising into the atmosphere the water vapour cools to form water droplets and fall back to the earth. This process is called "condensation". The cycle of transfer of water from the liquid to vapour state and vice versa is called the "hydrological cycle". The rivers are the major supply of water in Pakistan particularly the Indus River and its streams. The rainfall is scanty and its usefulness to farmers is limited. Ground water can be utilized only in those areas where the water-table is high. As water from the rivers is available all-round the year they constitute the most important source of water supply. Some of the material carried by a river is in solution the rest consists of solid fragments of various sizes and shapes. The smallest particles of rock sink very slowly and for most of their journey remain suspended in the water. The larger fragments are rolled along the bed and those of intermediate size move by hopping or saltation; by knocking against one another they become rounded and are formed into pebbles; by rubbing against the banks and bed they wear away the channel of the stream. The size of the pebbles that a river can move depends upon the velocity of the current. It depends also to a considerable extent upon the shape and material of the pebbles. Rivers depend for their supply mainly on oceanic rainfall. The monsoon type of climate also produces summer high water. Despite the considerable

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evaporation at that time the falls of rain are so great that rainfall alone controls the outflow. In long rivers, where the source of supply is in a climatic region very different from that of the lower parts, there may be great losses due to evaporation. There is also a dry season in monsoon countries, and at that time the rate of evaporation is also high. In consequences, the dry-season flow may fall very low, or even cease altogether. In mountain areas of temperature latitudes where a good deal of snow, as distinct from glacier-ice, accumulates on the high ground, there is produced a regime in which the maximum occurs usually in early summer; whereas in the colder parts of the year, the flow may still be considerable.

Regime signifies the totality of phenomena relating to alimentation of rivers and streams, and their variations in outflow. The volume of water in the river may vary much in the course of a year. The relations of discharge to weather, soil conditions, rock structure, and vegetation are as interesting as they are intricate, and present to the hydrologist many problems both of practical and theoretical aspects. Hydrology, in fact, is in many ways an important link between the physical and human sides of geography. The outflow of a river represents only a proportion of the precipitation falling on the river basin. The effect of evaporation is often great, and naturally varies much with temperature and so with the season of the year. No small part of the rainfall percolates in to the ground to reappear as springs, the fluctuations of which often reflect the variation in the rainfall some weeks or even months earlier. Of the moisture which percolates into the ground, a proportion is returned again to the atmosphere by the transpiration of plants. The local and general gradients of the country also have a marked effect on the outflow; other things being equal more water will go directly to the stream in steep country than in low-lying plains.

The transportation power of a river evidently depends upon its velocity and its volume or discharge. For it is much easier to carry a load of fine material than an equal mass of coarse material. The presence of the coarse material may also encourage the turbulence which greatly aids the movement of bed material by stirring up the bed. The upward movement of eddying motion may lift the bed material temporarily into the zone of quicker moving water where it will be carried a little downstream before it again falls to the bed. Turbulence shows a significant part in the transport of materials by rivers and streams. As the discharge of the stream increases (during floods), its transporting power increases at a greater rate than the discharge, but friction with the bottom and sides increases only slightly with discharge, so leaving all the more energy available for transport. A rapid stream can carry more material and can carry fragments of larger size than a slow one. Any stream without change of gradient or discharge can carry a greater of fine material.

It is often stated that for any particular river or part of a river (supposed to have a constant velocity and volume) there is a limit to the load that it can bear and when this limit is reached the load is called the full or maximum load of the river. The effect of adding more material to the load of a river is to reduce the velocity of the current, for much energy is lost in impelling the solid particles forwards. Thus the full load of a river depends not only on the velocity and volume of the river but also, and to a very important extent, upon the size, and mixture of sizes, of the particles constituting the load.

The erosion which a river accomplishes is of two types, chemical and mechanical. It may dissolve the rocks over which it flows, if they are of a suitable nature. This is chemical erosion or solution. It may break off fragments from its bed and banks. This is mechanical erosion or corrosion. In most cases, the corrosion is far greater than the solution, and it is accordingly with the corrosion. In order to see how the corrosion and the load interact upon one another, it will be convenient to assume at first that all the particles from which the load and which the river breaks off from its bank and bed are of the same material and the same size. There will then be a definite limit to the load that the river can carry. The velocity required to pick up loose material from a stream-bed is distinctly greater than that required simply to keep it moving and this in turn, is greater than that which occurs when deposition prevails. The disparity between the velocity necessary for erosion and the velocity necessary for transport is large in the case of fine clay particles owing to their power of cohesion. The river system of drainage is mainly the result of the earth movements to which the tilting of the surface and of the bed is due. It is therefore called the consequent drainage, and in such drainage the direction of the rivers is closely related to the geological structure. It has been suggested that this is why the Indus River break through the chain of the Himalayas. It may have existed before the elevation of the chain and has simply kept their original courses.

The main meteorological factors influencing the regimes of rivers are temperature, the annual precipitation, its distribution throughout the year and its nature-e.g. snow, and type of rainfall (evenly distributed, torrential but occasional, etc.). Temperature varies mainly with latitude and altitude, and with the season of the year. It is a factor of great importance since it very largely controls and rate of evaporation and evaporation may often have far more decisive effects on outflow than does rainfall. If the condensation in a cloud goes sufficiently far, the drops of water may coalesce into larger ones, which fall as drizzle or rain, depending to a large extent on the degree of vertical motion within the cloud. If the dew point is low enough, the vapour condensation into minute crystals of ice instead of drops of water, and these may unite and flakes of snow. The total amount of water that falls on any given areas whether in type of snow or rain or hail, is known as the precipitation, or more commonly as the rainfall. It is measured by means of a rain-gauge, which in principle is simply a funnel leading into a vessel of some kind to contain the rain that falls upon the funnel. The area of the opening of the funnel is known and by measuring the amount of water collected in the vessel beneath, we know much has fallen on that area. The rain is due to the cooling masses of the air which contains water vapour. Apart from local and temporary conditions there are two principle methods by which this cooling may be brought about. The air may flow to colder latitudes or it may rise to greater altitudes where both temperature and pressure are less. In either case, there will be a tendency to produce rain. Warm air impelled towards colder latitudes usually causes rain when it meets and rides over the colder air-masses lying in its path or it may be precipitated as drizzle or form fog by advection over colder surfaces. Where, on the other hand, the air is flowing to warmer latitudes or where it is descending, it will in general be able to take up more vapour and, in the ordinary sense of the word, it will be dry. The greatest rainfall will be in the middle of the equatorial low pressure, for there the rising air is most heavily charged with vapour. In general, the rainfall will be heavier over the sea than over the land because there are supply of vapour is greater.

From the earliest times it has no doubt been known to dwellers on the coasts of tidal seas that there is some connection between the tides and the moon. But the interval is not everywhere the same. In some places it is one hour, in others two and so on and moreover, even at the same place at varies to some extent. Gravitation is a mutual attraction which exists between all particles of matter in the universe. The earth attracts the moon and moon attracts the earth. The moon attracts every particle of matter in the earth. The attraction varies inversely as the square of the distance, and the moon, so attracts the parts of the earth which is nearest to it more strongly than the parts which are farthest away.

The river will begin to flow almost as soon as the land appears above the sea; but in order to show how they develop it will be simpler to suppose that the slope is completely formed before the river start. Suppose that in the manner described an uplift produces a region sloping directly and uniformly from a straight watershed to the sea and that the outcrops of two hard beds run parallel to the watershed, the beds dipping in the same direction as the slope but at a steeper angle. If there is no interference by earth movements or other causes, the largest of the original consequent rivers may capture in turn the head-waters of all the rest. The tributaries which effect the capture may become considerably larger than the original consequent river into which they flow, and the latter may be by comparison an almost insignificant stream down to its junction with its tributaries.

Erosion at the head of any stream depends upon rock type, climate (especially rainfall), slope and other factors. Weathering leads to the formation of soil which is gradually washed away. A river rising on a steep slope is likely to cut back more quickly than on a gentler slope and capture headword erosion implies a difference in level of the streams concerned. If the rocks of the divide are all impervious, capture cannot take place until the pirate stream has cut back through the divide to a level below that of the extreme flood level of the stream it is about to capture. Once this level is attained, the flood in the captured stream will aid in its own diversion. If there are previous rocks in the divide, it is probable that the capturing stream will draw off some of the ground water supply of the higher level stream. If this is the case, the flow of the lower stream will be increased and that of the upper decreased. But such a process will not be of much significance unless the rocks are soluble or very pervious. In limestone, for example, the interconnecting joint system is much more effective in this respect than the solubility of the rock. The process can take place in well-joined rocks, even if they are not soluble.

When water enters a narrow cleft in a rock and afterwards freezes, its expansion on changing into ice tends to widen the cleft. If this happens often, a part of the rock may be broken off. The consequence is that in mountain districts projecting crags are gradually broken up and the fragments are scattered on the mountain side, often forming screes. This kind of action goes on only in places where the temperature is sometimes below the freezing point and sometimes above and the more rapid the alternation the more rapid is the disintegration of the rock. Where, on the other hand, the temperature is always above freezing point the water never becomes ice, and where it is always below freezing point the ice never becomes water. It is accordingly on the borders of the polar region and towards the tops of mountains in other parts of the world that the effect is greater, and it is there so marked that in some enough to afford a hold in climbing.

Snow itself as it lies upon the ground is neither a disintegration nor corrosive agent. It may protect the rock beneath. It is a bad conductor of heat, and act as a blanket, preserving the ground from changes of temperature. As it begins to melt in the spring, however, moisture soaks through to the ground and in the night this freezes near the edges and where the snow is thin. This thaw-freeze process continues until the snow disappears. Downhill movement of comminuted material is aided because snow that lasts late into the summer kills the vegetation and keeps the soil bare. This downhill movement or creep leads to a general smoothing of the contours, and rocks projecting through the mantle of debris tend to be rounded off. If the snow lasts longer in one place than another, as when a greater thickness of snow accumulation in a slight hollow or on a ledge, the communication by thaw-freeze and the downhill movement act over a longer period. The material is broken up until it is fine enough to be removed by the smallest runnels from the melting snow. In this way, the hollow is slightly enlarged each year. A larger snow drift collects the next year and so the process continues.

The Storm precipitation has aacute influence in dischargeon Indus basin and its branches from April to September (Khan *et al.*, 2011). Annual rainfall varies from 1000-1400 mm in the entire territory. About 10% of the rainfalls is gone by dissemination and around a 41 million area of land foot is gone by spillage from unlined channels(Hassan *et al.*, 2010). The misfortunes could have been limited with the reasonable stream-stream assessing and improving the stream structures in Pakistan.

We have distinctive strategies for estimation of stream examination, for example, estimation of hydrological parameter and so on. An investigation assesses the danger of flow in River Indus of Pakistan by using recorded data of most peakdischarges which computes the arrival time of different dams in Pakistan utilizing probabilistic distribution e.g. Weibull distribution, Pearson type- 3 analysis (Khan *et al.*, 2011). GIS procedure is likewise utilized for surveying the flood chance. An ongoing report has been utilized nonlinear systems of anticipatingfor examining the long haul stream of the Indus River (Hassan *et al.*, 2010). Then completed an intensive report on the surge deciding structure for utilizing a reproduced neural framework (Coulibaly *et al.*, 2001) and they have revealed that there is a space for facilitate change for the NN demonstration. Currently, distinctive strategies have been delivered for gauging in which ARMA or NN model building procedures are well acknowledged or accepted.

In the worldview of man-made consciousness, delicate registering is characterized as a gathering of uncertain computational procedures, for example, Fuzzy Logic (FL) based processing, Evolutionary Computing (EC) and Nature Inspired Computing (NIC) that aid computational issues in loose situations which are not effectively resolvable through ordinary arithmetical strategies. A decent part of these systems is that it needn't bother with the model development apriority, rather than more often than not arrangement examination techniques. This examination here proposes to utilize delicate figuring approaches for the hydrological time arrangement of upstream stream on bring down Indus River basin of Pakistan.

2. RELATED WORK

Now days, an unnatural weather change shows up as a significant dangers to our globe. The fact that, due of the expansion of ozone harming substances in our external climate, the temperature has been increased to 0.74°C has been verified in the course of the most recent 100 years, prompting surges, starvations, dry seasons and violent winds and other cataclysmic events. Pakistan is additionally among those parts on earth that confronted these cataclysmic events in view of environmental change.

The water of the ocean is never still. It is blown into waves by the wind, it rises and fall with the tides and in many places there are definite currents either permanently in one direction or changing with the tide or with the season. When water is thrown into waves, they travel in some definite direction, but a cork must move with the water on which it floats and so it is clear that although the wave travels forward the particle of water do not. The crest is called the peak portion of the wave, the lowest the trough; the distance from crest to trough is called the length of the wave and the vertical height of the crest above the trough is height or amplitude. In deep water the motions of the particles are circular at all depths. At the crest the movement of the particles is forward, at the middle of the hinder slope it is downward, in the trough backward, and at the middle of the front slope upward.

The speed of waves depends partly upon their length and partly depends upon the depth of the water. When the water is shallow relative to the length of the wave, the velocity depends on the depth alone. When, on the other hand, the water is deep relative to the length of the wave, the velocity depends on the length alone. Consequently, in the open ocean the speed of a wind-wave depends upon its length, but on a shelving shore it depends upon the depth of the water. It is for this reason that on a sandy beach the crests of waves are nearly parallel to the shore whatever the direction of the wind may be. On such a shore the depth of the water gradually increases outwards. This, like the turning of the waves, is due in part to the fact that the wave travels more slowly as the water becomes shallower. The front of the wave is in shallower water than the back and therefore moves more slowly. The back gains upon it and the front becomes steeper, until in fact the crest is practically unsupported in front, and then, because of the forward movement of the particles at the top of the wave, the crest falls forward.

Estimates of summer run-off in the eastern parts of the United States and in the western Alps are, to an increasing extent, being based on estimates of winter snowfall. Snowfall surveys are carried out by direct measurement of snow depths in places chosen for their known reliability for indicating average snow depth over large areas. The density of the snow is also sampled. In examining the regime of a river, attention must be given to the nature of its basin in relation to rocks and rock-structure, position and orientation with respect to wind and rainfall, altitude, and plant cover. Many rivers with relatively short courses and situated wholly within one climatic area usually show a simple regime, with one period of high water in the year. Others, which are longer and joined by tributaries draining areas of different climates, may have a complicated outflow, or perhaps the variation in the tributaries may be such as to give the main stream, in its lower course, a simple regime.

The first type of regime includes streams fed by glaciers, those influenced by snow melting whether in mountains or plains, those whose main source of supply is oceanic rainfall, and the tropical rainfall type. When a river rises in a glacier, the period of high water is in the summer when melting is at a maximum. There will also be diurnal variation, since the melting is most rapid in the early afternoon. Variations will also depend upon altitude, since melting is likely to take place earlier in the season at lower altitudes, thus causing an earlier high-water period. In winter the flow is at a minimum and largely depending on local factors, there is a gradual increase in late spring and early summer and a corresponding decrease in late summer and early autumn.

Rivers depend for their supply mainly on oceanic rainfall. The monsoon type of climate also produces summer high water. Despite the considerable evaporation at that time the falls of rain are so great that rainfall alone controls the outflow. In long rivers, where the source of supply is in a climatic region very different from that of the lower parts, there may be great losses due to evaporation. There is also a dry season in monsoon countries, and at that time the rate of evaporation is also high. In consequences, the dry-season flow may fall very low, or even cease altogether. In mountain areas of temperature latitudes where a good deal of snow, as distinct from glacier-ice, accumulates on the high ground, there is produced a regime in which the maximum occurs usually in early summer; whereas in the colder parts of the year, the flow may still be considerable.

Most of the areas in Pakistan are dry and infertile to a great extent due to the immense changeability in climatic factors. The principle water asset of our country is dissolving snowfall from the Himalayan icy masses, and overwhelming rainstorm precipitation. While Pakistan itself contributes almost no to the worldwide discharges of the ozone harming substances, yet it stays a standout amongst the most seriously hit nations of the world by the course of a dangerous atmospheric deviation. An Earth-wide temperature boost has influenced the atmosphere of Pakistan by dissolving of icy masses, intermittent flooding, and dry spells.

Insufficient rainfalls that resulted in durations with extremely dry weathers is called a drought. The main characteristic of a drought is a lack of water in a particular period and over a territory. For many years, the economy of Pakistan has been facing severe spells of drought, particularly in Baluchistan and Sindh. This is resulting in reduced river flows, as well as aeration of the irrigation canals, which leads to a severe agricultural hardship. It has been an important cause for massive losses to poultry and other animals, resulting in lack of food and water for population. The increased greenhouse gases and mismanagement of the water reservoirs results in high temperatures and this is needed to be blamed for the condition.

The wrong maneuvers of the people have at long last begun to inflict significant damage on the world's condition, prompting the arrangement of an unstable air, which is subject to be adverse for the mankind itself as flighty synergist climatic occasions. The case of such ongoing occasions incorporates the assaulting dry spells of Australia and China in 2006 and Texas in 2011, the flood of Pakistan, Spain, and Northern of 2010 and 2011, 2011 and 2012 respectively Side of the equator summer which behead more than 2000 individuals. More than 10 million individuals have been dislodged while the most recent two years, the farming area lies fruitless and money related misfortunes have been evaluated at $2 billion. In this manner, there is a developing accord that means should be taken to evacuate the reason for these occasions. Notwithstanding the development of well idea surge and dry spell counteractive action approaches, ventures to lessen the general discharge of ozone harming substances must be taken with the goal that the planet Earth and its occupants can survive.

Above all it is the matter of the Water resource management. It's extremely odd that a nation has lack of water resources. In addition, a National water consumption strategy has been formulated without water approach and this increases numerous worries for its usage. Furthermore, selection of a Coordinated Water Assets Administration approach in the structure of the Water Accord 1991, based on utilization of both surface water and groundwater, is the need of great importance. This should be taken up by the Indus stream framework specialist as unchecked groundwater could lead towards its aggregate consumption. Thirdly, it is vital to audit the water reallocation at the common level by composing water accessibility to trimming designs. Finally, assessment of natural streams ought to be combined with evenhanded with earth or financially reasonable capacity, so the business of the general population along with the biological system supporting the work that can be secured.

Amid the most recent couple of decades, Pakistan has experienced distinctive cataclysmic catastrophes actuated by rainstorm expected surges. As per the Asian Development Bank, Pakistan has kept running into twenty outstanding surges something close to 1950 and 2012 that ensured a total of 8,887 human lives and conveyed damage to 109,822 in towns with a normal money related loss of $19 billion. The noteworthy explanation behind flooding in Pakistan is obliterating enlivened precipitation in the stream catchments which on occasion deferred by snowmelt streams that outcome the surges in the vast majority of part of streams amid the storm season. In the upper part of thebasin, surge water flooding the riverbanks generally returns to the stream. Along these lines, the hazard examination is performed by the event of surge occasions (Smith, 1997). The gauge of meteorological time arrangement displays an essential part in numerous fields. ARIMA models is used to exhibiting stream low resource arrangement in light of the way that such models are recognized as a standard portrayal of stochastic time arrangement (Maier and Dandy, 1997). Be that as it may, these models did not attempt to the non-coordinate stream innate in the hydrology frameworks, and might not for the most part perform well (Tokar and Johnson, 1999). An on-going report has utilized nonlinear techniques for examination and determining the proceeding with normal conduct of the Indus Basin (Hassan *et al.,* 2010). A usage of minimum squares bolster vector machine (LS-SVM) for brief desire for meteorological time arrangement (e.g. sun oriented light, air temperature, relative moistness, wind speed, wind heading and weight) was exhibited by (Mellit *et al.,* 2013) and this analysis shows that LS-SVM gives promising outcomes to transient gauge of meteorological data. In fuzzy rationale based performance, the structure characteristic evidence is depicted by utilizing fuzzy sets (Sugeno *et al.,* 1988).

3. DATA DESCRIPTION AND LOCATIONS

For upstream stream anticipating model, it isn't enhanced to make utilization of precipitation as a result of the prolonged distinction in time (request of days) amongst precipitation and the subsequent waterway water stream. As it were, there is a powerless connection amongst's precipitation and streams. Along these lines, the usage of stream perceptions is well on the way to receive for the great upstream stream gauging model. This paper considers mean month to month upstream stream perceptions of Lower Indus Basin (LIB) i.e. Sukkur Barrage from April to September (precipitation season) for every year, extending from 1977 to 2012 **(Fig. 1)** which obviously display the diminishing pattern in the recorded perceptions. This precipitation season is additionally isolated into two streams eras, the first is Low.

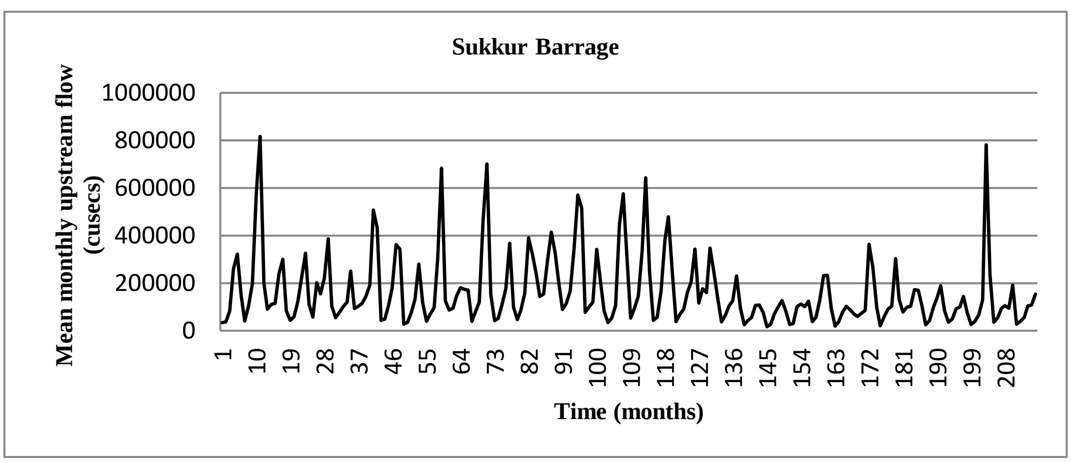

Fig. 1: Sukkur Barrage historical observations from April to September each year, ranging from1977 to 2012

Upstream Flow period (April, May, June) and the second is High Upstream Flow period (July, August, September). By utilizing the mean and standard deviation of upstream stream chronicled information, the qualities inside the interim (mean - standard deviation, mean+ standard deviation) indicates Average Flows and exterior the interim are known as the Lower Flows and Peak Flows individually.

4. FUZZY TIME SERIES

For the reason that fuzzy sets (FS) are the function tendencies of crisp units.fuzzy set hypothesis presents an aspect of observations and relationship between the additives of the sets (Zadeh, *et. al.*, 1965). A fuzzy set can be considered logically by assigning to each member in the universe of discourse to its diploma of membership within the FS. The maximum issues of actual systems are endure byambiguity, so every observation of a fuzzy time series (FTS) is said to be a fuzzy variable connected by a membership degree function (MF). Forecasting of FTSusing fuzzy modeling is possible that relies on fuzzy association and implication techniques (George, *et. al.*, 2008).

In fuzzy theory, matter of degree is significant in many real life situations. So the linkage of every member in a universe of discourse (S) is a matter of degree between 0 and 1 and signified by $\mu_F(S)$ where Frepresentsa FS and Srepresents the universe of discourse. Song *et. al.*, (1993, 1994) illustrated the aspects of FTSwhich depends on FSsas S(t) (t = …, 0, 1, 2, …) be the S and subset of R as well in which fuzzy set $f_i(t)$ (i= 1, 2, …) is defined onS(t). Suppose that the summation of $f_i(t)$ (i=1,2, …) is called F(t). Then, F(t) is said to be a fuzzy time series of S(t).

5. PARTICLESWARM OPTIMIZATION

A soft computing approach, called Particle Swarm Optimization (PSO), depends on the tendency of swarm (group) intelligence. In reality, it is a random phenomenon which is basically motivated by swarming (group or population) of birds. The PSO was put forward by James Kenndy and Russel Eberhart (Kennedy and Eberhart, 1995). By the search space of the problem, we take a swarm (group or population) that fly using this space. This algorithm is used for a personal own past best position, whole swarm's best overall position and the present movement of individuals to ensure and decide their next position in the search space for getting the minimization (or maximization) of the search problem space. In addition, two aspects c_1(self-confidence coefficient) and c_2(social confidence coefficient) and two random numbers between [0, 1] step up respectively to get the existence while there is another aspect, called inertia w in $[w_{min}, w_{max}]$, that is multiplied by present movement of the swarm (Eberhart and Shi, 2000). $\boldsymbol{V} = [v_1, v_2, \dots\dots, v_N]^t$is represented as the initial velocity of the group or swarm in which N is the size of the swarm. Thus, each individual $\boldsymbol{X_i}$has the velocity as $V_i = [v_{i,1}, v_{i,2}, \dots\dots, v_{i,D}]$ where D represents the total number of variables or dimension of each individual of the group or swarm.The detailed algorithm of PSO is given (Eberhart and Shi, 2000)that shows the steps of the procedure.

6. PROPOSED METHOD OF FUZZY MODELING

This research study proposes anefficient data-driven fuzzy modeling algorithm which basically consists of fuzzy time seriesand an intelligent optimization method, called PSO, for finding the parameters (weights) of the new defuzzification method. This algorithm linked with fuzzification process which is based on trapezoidal fuzzification (Poulsen, 2009) and defuzzification process, called Mid-Variation Method, is accomplished to acquire the forecasted. The steps of the proposed algorithmare given as under:

1.Set the past observations of water flow(1977-1994) inascending order for training phase.
2.Determine the mean variation and the standard deviation between of any two successiveobservations by employing the following equations:

$$MV = MeanVariation(x_1, x_2, \dots, x_n) = \sum_{i=1}^{n-1} \left| x_{t(i)} - x_{t(i+1)} \right| \quad \dots\dots\dots\dots\dots\dots \quad (2)$$

$$SD_{(MV)} = Standarddeviation(x_1, x_2, \dots, x_n) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - MV)^2} \quad \dots\dots\dots\dots\dots\dots \quad (3)$$

3.Find and eliminate outliers defined as a value less or greater than one standard deviation ($SD_{(MV)}$) from the mean variation (MV) of the ordered values i.e. $MV \pm SD_{(MV)}$.
4. By eliminating the outliers, compute the revised mean variation (MV_R) by employing Equation2.
5. Compute the universe of discourse U, subtracting and adding the (MV_R) from the lowest and highest data respectively, values as in step 1 i.e.$U = [\, U_l \,, U_u]$.
6.Get the fuzzy sets (linguistic values) $F_1, F_2, F_3, \dots\dots.. F_n$ defined on U by estimating the trapezoidal fuzzy numbers which combine to the length of *left spreadlength*, *the core length*, and *the right spread length* of the membership function. The dividing the universe of discourse based on features of observations. So, the patterns of membership function of every fuzzy set are demonstrated asymmetric graph.
Determine the RangeR= $upperbound(U_u) - lowerbound\ (U_l)$

Determine the number of fuzzy sets $N_{FS} = \frac{R-(MV_R)}{2(MV_R)}$ (4)

The trapezoidal function employed to acquire the membership degree function(μ_F)relate toeach datum by using equation (5).

$$\mu_F = \text{trapezoid}(x; a, b, c, d) = \max(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0) \quad . \quad (5)$$

7.Employ trapezoidal fuzzification methodology to fuzzifyordered observation. Built on related fuzzy numbers, if value of the data of the month $i$linksto fuzzy set F_j , where $1 \leq j \leq N_{FS}$, then the value of the month i is fuzzified asF_j .

8.Find the mid-values $m_1, m_2, m_3, \ldots \ldots . . m_n$ of intervals (*left* or *core* or right), relating to each fuzzified linguistic term F_i where $1 \leq i \leq n$, in which the value of the data lies in. If $m_i = m_{i+1}$, then take the mid-value of the core length of F_i relating to m_i.

9. Now find the forecasted value at month i by employing a new defuzzification method, called Mid-Variation Method (MVM).

$$F_i = (MVM)_i = \frac{\frac{m_{i-1}}{v_{i,i-1}} + \frac{m_{i+1}}{v_{i,i+1}}}{\frac{w_1}{v_{i,i-1}} + \frac{w_2}{v_{i,i+1}}} \qquad (6)$$

where m_i = mid-value at month i
m_{i-1} = mid-value at previous month $i-1$
m_{i+1} = mid-value at one month ahead $i+1$
$v_{i,i-1}$ = variation from m_i to m_{i-1}
$v_{i,i+1}$ = variation from m_i to m_{i+1}
w_1 and w_2 are the weights which are to be determined using Particle Swarm Optimization (PSO)with the following standard values of the parameters (Shi *et al.*, 1998) by taking a swarm size (N=25) and maximum iterations (Maxite = 500).
w_{min}=minimum weight of inertial =0.4;
w_{max}=maximum weight of inertial =0.9
c_1=acceleration coefficient towards Pbest = 2
c_2=acceleration coefficient towards Gbest = 2
The minimum and maximum values (position) of the weights (w_1 or w_2) are limited to the following interval:

$$I_i = [\frac{m_{i-1}}{m_i}, \frac{m_{i+1}}{m_i}]$$

or ……………….. (7)

$$I_i = [\frac{m_{i+1}}{m_i}, \frac{m_{i-1}}{m_i}]$$

So that the fitness function
Squared Error (SE) = $(Actual - forecasted)^2$
should be less than one.

10. Perform assessment accuracy and errormeasurements as under:

$$MeanAbsoluteError = MAE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Q_i^o - Q_i^f}{Q_i^o}\right|$$

$$\text{Mean Squared Error} = MSE = \frac{\sum_{i=1}^{n}\left(Q_i^o - Q_i^f\right)^2}{n}$$

$$\text{Root Mean Squared Error} = \text{RMSE} = \sqrt{MSE}$$

$$\text{Coefficient of Correlation} = \rho = \left[\frac{\sum_{i=1}^{n}(Q_i^o - \bar{Q}^o)(Q_i^f - \bar{Q}^f)}{\sqrt{\sum_{i=1}^{n}(Q_i^o - \bar{Q}^o)}\sqrt{\sum_{i=1}^{n}(Q_i^f - \bar{Q}^f)}}\right]$$

$$CoefficientofDetermination = R^2 = \frac{\sum\left(Q_i^f - \bar{Q}^o\right)^2}{\sum(Q_i^o - \bar{Q}^o)^2}$$

where Q_i^o= observed upstream flow at time t
Q_i^f = forecasted upstream flow at time t

$$PeakFlowErrorCriteria = PFEC = \frac{(\sum_{i=1}^{p}((Q_i^o - Q_i^f)^2 * (Q_i^o)^2))^{0.25}}{(\sum_{i=1}^{p}(Q_i^o)^2)^{0.5}}$$

$$LowFlowErrorCriteria = LFEC = \frac{(\sum_{i=1}^{l}((Q_i^o - Q_i^f)^2 * (Q_i^o)^2))^{0.25}}{(\sum_{i=1}^{l}(Q_i^o)^2)^{0.5}}$$

where p = number of peak flows
l = number of low flows

Now, by repeating the procedure or steps of the proposed algorithm for relating observations of defuzzification weights w_1 and $w_2$which were found out in training phase for the testing phase(1995-2012).

7. RESULTS AND DISCUSSION

By applying the proposed fuzzy modeling algorithm in the training phase, numerical results are shown in **Table 1(a,b)** that represent the partitions independently. Depended on trapezoidal fuzzy numbers match to each fuzzified linguistic term (fuzzy sets) as in **Table 1(a)**, we showed fuzzy time series (FTS) objectively utilizing **Eqs. (4) and (5).** Now calculating the mid-values of each fuzzy numbers, soestimated the forecasted values by employed a new parameterized defuzzification method MVM using **Eq. (6)** in which the intervals parameters (weights)were calculated using **Eq. (7)** and the values of the weights were determined by employing a technique fPSO.

The computational numerical results are exhibited in **(Tables 2 and 3)** for training and testing phase respectively. The value of revised mean variation in testing phase is more as compare to training phase which shows the difference in number of fuzzy sets.

The error measurements and accuracy of training phase in Table 2 presents the encouraging results in terms of less than one error measurements and coefficient of determination which exhibit the proficiency of the proposed fuzzy algorithm. The numerical estimations of testing phase in Table 3 and **(Fig. 2)** are satisfied with error bound and the correlation to analyze the algorithm as an acceptable fuzzy model. The other interest of water resource operators is to analyze the extreme events. Thus, the computational results of **(Table 4)** shows this competency by estimating Low Flow Error Criteria (LFEC) and Peak Flow Error Criteria (PFEC) for both seasons of Low upstream flows period (April, May, June) and High upstream flows period (July, August, September). Because LFEC and PFEC show good operational indices for assessment of model appropriateness for the extreme events (Kaczmarek *et al.*, 2004),

Table 1(a): Fuzzification of upstream flow gauge observations

S. No.	Time Scale	Observations (gauge) (cusecs) round-off	Observations (ascending order)	Variation	Variation (revised)	Fuzzy Sets	Trapezoidal Fuzzy Numbers (a, b, c, d)			
1	1977	34385	27914			F1	23572	27914	32224	36533
2		37258	34385	6471	6471	F2	32224	36533	40843	45152
3		82405	34417	32	32	F3	40843	45152	49462	53771
4		261705	35059	642	642	F4	49462	53771	58081	62390
5		321937	37258	2199	2199	F5	58081	62390	66700	71009
6		147178	39358	2100	2100	F6	66700	71009	75319	79628
7	1978	41334	39826	468	468	F7	75319	79628	83938	88247
8		103495	41334	1508	1508	F8	83938	88247	92557	96866
9		198643	42693	1359	1359	F9	92557	96866	101176	105485
10		571210	43157	464	464	F10	101176	105485	109795	114104
11		816606	43344	187	187	F11	109795	114104	118414	122723
12		199593	46529	3185	3185	F12	118414	122723	127033	131342
……	……	……..	………	…….	…….	……	…….	…….	…….	……
97	1993	76670	415041	24280	17050					
98		100514	432091	17050	14985					
99		120615	447076	14985	19057					
100		342064	466133	19057	7159					
101		204618	507570	41437	479					
102		84554	514729	7159	4030					
103	1994	34417	570731	56002	17284					
104		52959	571210	479						
105		105775	575240	4030						
106		447076	683388	108148						
107		575240	700672	17284						
108		319273	816606	115934						

Table 1(b): Forecasting of upstream flow gauge observations

S. No	Time *Scale*	Fuzzy Time Series	Membership Degree	Mid Values	intervals of weights (Parameters)		w1	w2	forecast
1	1977	F2	0.501508	34378.5					
2		F2	1	38688	0.888609	2.113911	0.98255	1.596459	37258.7
3		F7	1	81783	0.473057	3.213162	0.582547	2.71401	82405.6
4		F28	1	262782	0.31122	1.229593	0.452597	1.18795	261705.9
5		F35	1	323115	0.813277	0.453168	0.80123	0.498816	321937.7
6		F15	0.674634	146425.5	2.206685	0.293648	0.81126	1.10237	147178.6
7	1978	F2	0.886052	42997.5	3.405442	2.403175	2.01271	3.39222	41334.42
8		F10	0.538176	103330.5	0.416116	1.917532	0.81112	1.29271	103495.6
9		F21	0.616848	198139.5	0.521504	2.892361	0.6651	2.31192	198642.5
10		F64	1	573091	0.345738	1.421155	0.4765	1.342393	571210.7
11		F92	1	814451	0.703653	0.24328	0.60712	0.484391	816606.8
12		F21	0.837317	198139.5	4.110493	0.456254	0.41251	1.094141	199593.5
…..	……	……	……….	………..	…….	………	………	………	………
97	1993	F6	0.68647	77473.5	6.618405	1.278127	1.3263	1.556911	76670.91
98		F9	1	99021	0.782395	1.217605	0.85372	1.11656	100514.6
99		F11	0.510791	120568.5	0.821284	2.822902	0.996373	1.0326	120615.8
100		F37	1	340353	0.354245	0.607483	0.456382	0.541282	342064.8
101		F21	0.996751	206758.5	1.646138	0.416392	0.553352	1.42333	204618.4
102		F7	0.857043	86092.5	2.401586	0.39932	0.451126	1.26121	84554.88
103	1994	F2	0.508935	34378.5	2.504254	1.501418	1.510214	1.8301	34417.76
104		F4	0.811557	51616.5	0.666037	2.08538	0.750263	1.70384	52959.88
105		F10	1	107640	0.479529	4.16296	0.590435	3.61371	105775.6
106		F49	0.737819	448101	0.240214	1.278933	0.505621	1.184628	447076.9
107		F64	1	573091	0.781902	0.556291	0.686378	0.742605	575240.7
108		F34	0.608494	318805.5					

Table 2: Assessment and error measurements of training phase(1977-1994)

No.of Observations	**Mean Variation (MV) (cusecs)**	**Standard Deviation (SD) (cusecs)**	**Mean Variation (revised) (MV_R)**	**lower bound (cusecs)**	**upper bound (cusecs)**	**Number of Fuzzy Sets**	**MAE**	**RMSE**	**R^2**
108	7371	16590	4342	23572	820948	92	0.000652	0.73231	0.98

Table 3: Assessment and error measurements of testing phase (1995-2012)

No. of Observations	Mean Variation (MV) (cusecs)	Standard Deviation (SD) (cusecs)	Mean Variation (revised) (MV_R)	lower bound (cusecs)	upper bound (cusecs)	Number of Fuzzy Sets	MAE	R^2	Correlation
108	7142	22892	2874	14012	783968	134	0.31	0.52	0.72

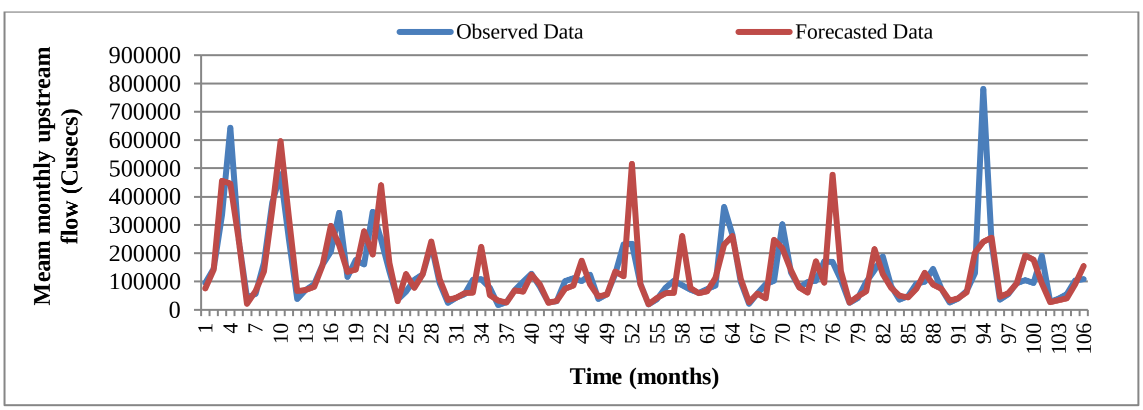

Fig. 2: Observed and forecasted upstream flows in testing phase at Sukkur barrage

Table 4: Low and Peak FlowsErrors Criteria of extreme events:

Flow Time Periods	Training Phase		Testing Phase	
	LFEC	PFEC	LFEC	PFEC
Low upstream flow	0.004002	_	_	_
High upstream flow	_	0.000608	_	0.458

8. CONCLUSIONS

The proposed fuzzy modeling algorithm is made without prior knowledge of the model by employing a fuzzy time series with a new parameterized defuzzification method MVM in which the parameters were determined by utilizing a soft computing technique, called PSO. The one feature of the algorithm is that it carries out the partitions of interval impartially or without assuming the number of intervals. The promising consequences of the training phase has sufficient agreement between actual and forecasted values with adequate estimates of accuracy and less than one errors measurements in Table 2. In order to investigate theproposed fuzzy algorithm, we analyzed 50% of historical observations in testing phase in Table 3 in which we have not as a large value of coefficient ofdetermination but it is plausible because there is an immense difference in revised mean variation and number of fuzzy sets in both training and testing phases. Moreover, the values of error measurement and coefficient of correlation from the findings of Table 3 are sufficient to obtain this proposed algorithm as an appropriate fuzzy model. Table 4 represent the proposed model adequacy for extreme events by utilizing the Low Flow Error Criteria (LFEC) and Peak Flow Error Criteria (PFEC) for both time periods of Low Upstream Flows (April, May, June) and High Upstream Flows (July, August, September) with sufficient LFEC by 0.4% for Low flows or PFEC by 0.06% for High flows for training phase (1977-1994) and low errors for testing phase (1995-2012) which shows the evidence of goodness of fit. By putting it another way, there is on average 0.23% error in training phase which do better for adequacy; similarly, no Low Flows observations and adequate precision for High Flows in testing phase. As a future research, extend the proposed approach with other soft computing techniques such as Genetic Algorithms (GA) or Differential Evolution (DE) to accomplish the optimal behavior and higher accuracy of the system.

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