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Application of Data Clustering Embedded in Fuzzy Classifier Expert System for Water Quality Recognition

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ABSTRACT: Water is the energy of life. Its usage and want far out stretch any Earth material (minerals, rocks, soil and water). In most cases the quantity of water obtains from its different sources are not quality enough for human usage due to the presence of contaminants. The application of several criteria for the recognition of water quality ("Might be pure", "pure" and "Not pure") is the focal point of this paper. The conventional (traditional) methods for water quality recognition employed by different individuals are expressed using Fuzzy classifier. The proposed expert system eliminates uncertainties and imprecision associated with the recognition of water quality. @JASEM

Keywords: Fuzzy classifier, fuzzy logic, fuzzy set, Water

All things are water Aristotle attributed this teaching to the Thales of Miletus, the first known Greek philosophers, scientist and mathematician (AGI, 2002). The phrase above highlights the importance of water. Earth, is the only planet in our solar system presently characterized and shaped by abundant liquid water; a necessity for life like the air we breathe. This vital resource makes up 60 percent of the human body. A person can live no more than 4 to 5 days without water. We rely on it for drinking, cooking, bathing, washing clothes, recreation, industry, generation of electric power (hydroelectricity) and mining (AGI, 2002 and Wikipedia, 2011). Water is a major factor in shaping our landscape. Through the processes of erosion and sediment transport, water forms many surface feature such as valleys, flood plains, deltas and beaches. Natural wonders such as the Grand Canyon are being, carved by water. Streams from upland areas carried much of the sand that is located on ocean beaches (AGI, 2002 and Wikipedia, 2011).

Water is a chemical substance with the chemical formula H_2O. Its molecule contains one molecule of oxygen and two molecules hydrogen atoms connected by covalent bonds (a chemical bonding that is characterized by the sharing of pairs of electrons between atoms). Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state, ice and gaseous state (water vapor or steam). Water also exists in a liquid crystal state near hydrophilic surfaces (Wikipedia, 2011). Water covers 70.9% of the Earth's surface, and is vital for all known forms of life (Wikipedia, 2011). On Earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air) and precipitation. Oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6%. A very small amount of the Earth's water is contained within biological bodies and manufactured products (AGI, 2002 and Wikipedia, 2011). Water on Earth moves continually through a cycle of evaporation (transpiration), precipitation and runoff, usually reaching the sea. Over land, evaporation and transpiration contribute to the precipitation over land. Clean drinking water is essential to humans and other life forms. The basic source of all fresh water is from precipitation (Sebastian et al. 2010), which may be in various forms such as rain, snow, hail, and dew. This from the atmosphere may either remain on surface or go underground. The surface and sub-surface sources of water are categorized as follows (Wikipedia, 2011) surface sources, ponds and lakes, streams and rivers, storage reservoirs, sub-surface/underground sources, wells, tube wells and springs. In the surface sources of water supply, the water drawn from lakes and reservoirs is considered most safe, due to settlement of suspended materials usually present in the water.

Rivers and streams are the most important sources for public water supply schemes. The importance of water from quality viewpoint had been recognized for a long time now. That is why most of the present urban centers grew up on the banks of major rivers, which enacted continuous and regular water supply to the inhabitants (Wikipedia, 2011). In most of the rivers, the quality of water flow is not constant round the year but is based upon various factors including seasons. Thus to overcome this problem and to ensure a regular supply of water, a barrier in the form of a dam is constructed across the river to store the excess water that flows during the monsoon season. The pool so created upstream of a dam constitutes the storage reservoir. Smaller reservoir may also be termed as artificial lake. Water is a renewable resource. However, it is not always available when or where it is needed, and it may not be of suitable

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quality for intended uses. Similarly, the quality of water obtained directly from rivers is usually not useful for direct human consumption due to the presence of contaminants (impurities). A contaminant is an undesirable substance in water that either is not normally present or is a naturally occurring substance at an unusually high concentration thereby increases it impurities. Contaminant can impair water quality and affect water usage. Contaminants can be divided into four general classes: sediment and natural organic materials, nutrients, bacteria, and toxic substances. These can contribute to water by either point or non-point sources (AGI, 2002). The practice of discharging untreated sewage into the river increases such impurities in the water. Thus the water from majority of surface sources could be contaminated and cannot be used without treatment or purification (Wikipedia, 2011).

The focal point of this paper, centers on recognizing clean, portable water for human usage utilizing data clustering embedded in fuzzy classifier. Fuzzy Logic provides a means of representing and manipulating data that are not precise, but rather fuzzy. The theory of fuzzy logic utilizes mathematical strength to capture the uncertainties associated with human cognitive processes. Existing methods (traditional or conventional) for analyzing (test data) of water uses approaches (techniques) that are unable to handle uncertain or vague data. In this paper, the rich facilities of fuzzy classifier is utilize for dealing with such uncertainties.

The parameters (criteria's) set out in several literatures for the identification of pure water includes (Ezine, 2011 and Wikipedia, 2011).

pH value of 7: In chemistry, pH is a measure of the acidity or basicity of an aqueous solution (Betas, 1973). Pure water is said to be neutral, with a pH value of 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. pH measurements are important in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering and many other applications (Fang et al. 2005). Mathematically pH is defined as a negative decimal logarithm of the hydrogen ion activity in a solution.

$$\mathrm{pH} = -\log_{10}(a_{\mathrm{H}^+}) = \log_{10}\left(\frac{1}{a_{\mathrm{H}^+}}\right)$$

Where $a_{\mathrm{H}}+$ is the activity of hydrogen ions in units of mol/L (molar concentration).

Freezing point of water at one atmosphere is 0.00C: Most liquids including water, at such temperature must freeze, failure of such liquid to freeze indicate the presence of contaminants (impurities).

Low water density: Temperature, salinity and pressure work together determine water density (weight of water divided by the amount of space it occupies). Cold, salty water is much denser than warm, fresher water and will sink below the less dense layer. The lesser the density of water at a particular measure indicate it purity compare with more dense water at that same measure.

Water turbidity: Turbidity, a measure of the cloudiness of the water, is commonly used as a proxy measure for the risk of microbial contamination and the effectiveness of the treatment of public drinking water (EPA, 1984). Several studies have shown a correlation between turbidity levels and microbial contamination of raw and treated water (Clark et al., 1992). Much turbidity is an indicator for high water impurities while less or no turbidity simple means water might be pure.

Dissolved oxygen: Oxygen saturation or dissolved oxygen (DO) is a relative measure of the amount of oxygen that is dissolved or carried in a given medium. It can be measured with a dissolved oxygen probe such as an oxygen sensor or an optode in liquid media, usually water. It has particular significance in medicine and environmental science. The presence of much dissolve oxygen in waters simple means water might not pure because it can support more microorganisms and little or no dissolved oxygen might indicate water purity (Wikipedia, 2011).

Temperature of water (Boiling point): When water is heated up to 100C or 212 f, or 373 k, it is usually pure for human consumption because at this point most microorganisms cannot survive at such temperature.

High Osmotic Pressure: The phenomenon of osmotic pressure arises from the tendency of a pure solvent to move through a semi-permeable membrane and into a solution containing a solute to which the membrane is impermeable. This process is of vital importance in biology as the cell's membrane is selective towards many of the solutes found in living organisms. Usually high osmotic pressure might indicate pure water while low osmotic pressure is associated with contaminants embedded in the water.

High Conductance: Conductivity is the measures of the ability of a fluid to conduct electrical current. Conductivity is simply the reciprocal of resistivity: conductivity =1/resistivity. In practice, conductivity units are typically used when referring to water ranging from drinking water to sea water. Low conductivity simple means water is not pure, while pure water usually has high conductivity (WikiAnswer, 2011).

Presence of Chlorine: Chlorine is one of the most widely used disinfectants. It is very applicable and very effective for the deactivation of pathogenic microorganisms in liquid including water. Chlorine can be easily applied, measures and controlled. Chlorine has been used for applications, such as the deactivation of pathogens in drinking water, swimming pool water and wastewater, for the disinfection of household areas and for textile bleaching, for more than two hundred years (LennTech, 2011).

Expert systems are knowledge-based systems that contain expert knowledge. An expert system is a program that can provide expertise for solving problems in a defined application area in the way the experts do. They use human knowledge to solve problems that normally would require human intelligence. These expert systems represent the expertise knowledge as data or rules within the system. These rules and data can be called upon when needed to solve problems (PCAI, 2002; NIJ 2011 and Steffen 2011).
Fuzzy systems are rule-based expert systems based on fuzzy rules and fuzzy inference. Fuzzy sets were introduced by (Zadeh 1965) to represent/manipulate data and information possessing non statistical uncertainties. Fuzzy sets provide a means of representing and manipulating data that are not precise, but rather fuzzy. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between "completely true" and "completely false" (Christos and Dimitros, 2008; Kasabov, 1998 and Robert 2000). The theory of fuzzy logic provides a mathematical strength to capture the uncertainties associated with human cognitive processes, such as thinking and reasoning. A fuzzy set A is called trapezoidal fuzzy number (Figure 1) with tolerance interval [a, b], left width α and right width β if its membership function has the following form

$$A(t) = \begin{cases} 1 - (a - t)/\alpha & \text{if } a - \alpha \le t \le a \\ 1 & \text{if } a \le t \le b \\ 1 - (t - b)/\beta & \text{if } a \le t \le b + \beta \\ 0 & \text{otherwise} \end{cases}$$

and we use the notation A = (a, b, α, β). It can easily be shown that $[A]^{\gamma} = [a - (1 - \gamma)\,\alpha,\ b + (1 - \gamma)\,\beta]$, ∀ γ ε [0, 1]. The support of A is (a – α, b + β).

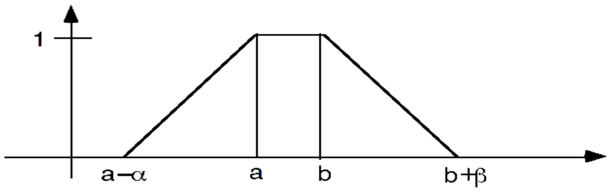

Fig 1: *Trapezoidal fuzzy number*

Fuzzy systems often learn their rules from experts. When no expert gives the rules, adaptive fuzzy systems learns by observing how people regulate real systems (Leondes, 2010). The difference between classical and fuzzy logic is something called "the law of excluded middle" (Bart and Satoru, 1993 and Ahmad, 2011). In standard set theory, an object does or does not belong to a set. There is no middle ground. In such bivalent systems, an object cannot belong to both its set and its compliment set or to neither of them. This principle preserves the structure of the logic and avoids the contradiction of object that both is and is not a thing at the same time (Zadeh, 1965). However, fuzzy logic is highly abstract and employs heuristic (experiment) requiring human experts to discover rules about data relationship (Angel and Rocio, 2011).

Fuzzy classification assumes the boundary between two neighboring classes as a continuous, overlapping area within which an object has partial membership in each class (Kuang; Ting-Hua and Ting-Cheng, 2011). It not only reflects the reality of many applications in which categories have fuzzy boundaries, but also provides a simple representation of the potentially complex partition of the feature space. An adaptive-network-based fuzzy classifier to solve fuzzy classification problems was proposed by (Sun and Jang, 1993). Conventional approaches of pattern classification involve clustering training samples and associating clusters to given categories. The complexity and limitations of previous mechanisms are largely due to the lack of an effective way of defining the boundaries among clusters. This problem became more intractable when the number of features used for classification increased (Christos and Dimitros, 2008; Kasabov, 1998; Robert 2000 and Rudolf, 2008).

Fuzzy classifier is a subset of fuzzy system since there fully application is only utilized using fuzzy system. While the fuzzy system on one hand operate an object into class (enabling them to work together), fuzzy classifier provide the fuzzy self learning rule (conditional statement) which enable the system to be fully optimal. Fuzzy systems are fundamental methodologies to represent and process linguistic information, with mechanisms to deal with uncertainty and imprecision (Reza and Ali, 2011).

Cluster analysis or clustering is the assignment of a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense. Clustering is a method of unsupervised learning and a common technique for statistical data analysis used in many fields, including machine learning, data mining, pattern recognition, image analysis and bioinformatics. A cluster is therefore a collection of objects which are "similar" between them and are "dissimilar" to the objects belonging to other clusters (Osama, 2008). The goal of clustering is to determine the intrinsic grouping in a set of unlabeled data.

METHODOLOGY

Fuzzy classifier is applied to the quality of water (Might be Pure, Pure and Not Pure) using the model prescribed in Fig 2.

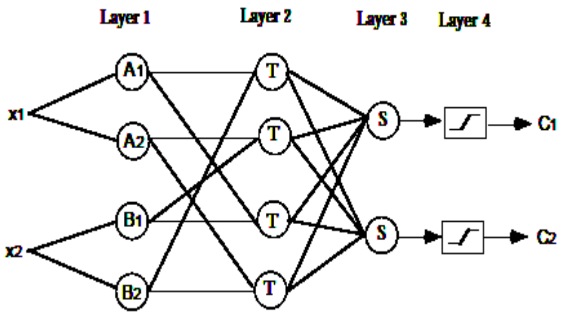

***Fig 2:** Fuzzy Classifier System for Water quality*

The system parades two input variables X_1 and X_2 which are parameters (criteria's) of clean water. The training data are categorized by two classes C_1 and C_2. Each input is represented by the two linguistic terms, thus we have four rules.

Layer 1: The output of the node is the degree to which the given input satisfies the linguistic label associated to this node. This is governed by the bell-shaped membership functions

$$\boldsymbol{A_i (u) = \exp [-1/2 (u\text{-}a_{i1}/b_{i1})^2],}$$
$$\boldsymbol{B_i (v) = \exp [-1/2 (v\text{-}a_{i2}/b_{i2})^2],}$$

which represent the linguistic terms, where (a_{i1}, a_{i2}, b_{i1}, b_{i2}) is the parameter set. As the values of these parameters change, the bell-shaped functions vary accordingly, thus exhibiting various forms of membership functions on linguistic labels A_i and B_i. In fact, any continuum, such as trapezoidal and triangular-shaped membership functions are also quantified candidates for node functions in this layer. The initial values of the parameters are set in such a way that the membership functions along each axis satisfy; completeness, normality and convexity. The parameters (criteria's) are then tuned with a descent-type method.

Layer 2: Each node generates the signal corresponding to the conjunctive combination of individual degrees of match of water parameters. The output signal is the firing strength of the fuzzy rule with respect to waters.

We take the linear combination of the firing strengths of the rules at Layer 3 and apply sigmoidal function at Layer 4 to calculate the degree of belonging to a certain class.

Given training set $\{(x^k, y^k), k = 1 \ldots K\}$ where x^k refers to the k^{th} input pattern then

$$Y^K = \begin{cases} (1, 0)^T \text{ If } X^K \text{ belongs to Class 1} \\ (0, 1)^T \text{ If } X^K \text{ belongs to Class 2} \end{cases}$$

The error function for pattern k can be defined by $E_K = 1/2\ [(0_1^K - Y_1^K)^2 + (0_2^K - Y_2^K)^2]$ where y^k is the desired output and o^k is the computed output.

Using fuzzy IF-THEN rules to describe a classifier**,** assume that K patterns $x_p = (x_{p1}, x_{pn})$, $p = 1...K$ is given from two classes, where x_p is an n-dimensional crisp vector.

IF x_{p1} is small and x_{p2} is very large THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_1
IF x_{p1} is large and x_{p2} is very small THEN $x_p = (x_{p1}, x_{p2})$ belongs to Class C_2

Where x_{p1} and x_{p2} are the features of pattern (or object) p, small and very large are linguistic terms characterized by appropriate membership functions

The task of fuzzy classification of water is to generate an appropriate fuzzy partition of the feature space. In this context the word appropriate means that the number of misclassified patterns is very small or zero. Then the rule base should be optimized by deleting rules which are not used. The scheme is extensible to any number of input and classes.

RESULTS AND DISCUSSION

The fuzzy partition for each input feature consists of water parameters (pH value of water, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity, no presence of dissolved oxygen, temperature of water (boiling point), high osmotic pressure, high conductance, presence of chlorine). However, it can occur that if the fuzzy partition of water is not set up correctly, or if the number of linguistic terms for the input features is not large enough, then some patterns will be misclassified. The rules that can be generated from the initial fuzzy partitions of the classification of water is thus

a. Might be Pure Water (C_1)
b. Pure Water (C_2)
c. Not Pure Water (C_3)

If the water is exhibit at least four parameters (C_1), if the water exhibit at least five or more parameters (C_2) and if the water exhibit less than four parameters (C_3)

The Fuzzy IF-THEN Rules (R_i) for water is

R1: IF the water possesses pH value of 7 THEN he/she has class C_3.

R2: IF the water possesses pH value of 7 and freezing point of water at one atmosphere is 0.00C THEN he/she has class C_3.

R3: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C and low water density THEN he/she has class C_3.

R4: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density and no water turbidity THEN he/she has class C_1.

R5: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity and no presence of dissolved oxygen THEN he/she has class C_2.

R6: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity, no presence of dissolved oxygen and temperature of water (boiling point) THEN he/she has class C_2.

R7: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity, no presence of dissolved oxygen, temperature of water (boiling point) and high osmotic pressure THEN he/she has class C_2.

R8: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity, no presence of dissolved oxygen, temperature of water (boiling point), high osmotic pressure and high conductance THEN he/she has class C_2.

R9: IF the water possesses pH value of 7, freezing point of water at one atmosphere is 0.00C, low water density, no water turbidity, no presence of dissolved oxygen, temperature of water (boiling point), high osmotic pressure, high conductance and presence of chlorine THEN he/she has class C_2.

The degree of intensity of water parameters ordered in the following classes for a typical scenario is presented in Table 1. From Table 1, Cluster 1 represent possible situation of “Might be Pure water” because four of the parameters of pure water are present. Cluster 2, represent possible situation of “Pure water” since five of the parameters of pure water is pronounced. Cluster 3 represent possible situation of “Not Pure water” since only a parameter of pure water are pronounced.

For instance, P09 in cluster 1, we notice it has 0.50. In term of percentage the degree of membership could be represented 50%, in cluster 2, 37% and in cluster 3, 13%. This means that the degree of parameters of P09 matches 50% of “Might be Pure Water”, 37% of “Pure Water”, and 10% of “Not Pure Water”.

Conclusion: This work demonstrates the application of Information and Communication Technology (ICT) in the domain of differential recognition of water quality utilizing fuzzy classifier method when given a set of parameters. Utilizing fuzzy classifier methodology, differential recognition of water quality is categorized into three main groups “Might be Pure water”, “Pure Water” and Not Pure Water” were presented. The system is designed to recognize pure water and not for water treatment, but can be expanded to do so in future research. A system of this nature that has the ability to recognize pure water is an essential feature in every facet of human endeavor and should be utilized.

Table 1: *Degree of Intensity of water parameters Scale (0.00 -1.00)*

PARAMETERS (CRITERIA'S) OF WATER	WATER PARAMETER CODES	DEGREE OF MEMBERSHIP OF WATER QUALITY		
		CLUSTER (C_1)	CLUSTER (C_2)	CLUSTER (C_3)
pH Value of 7	P01	0.50	0.00	0.50
Freezing point of water at one atmosphere is 0.00C	P02	0.25	0.60	0.15
Low water density	P03	0.25	0.50	0.25
No water turbidity	P04	0.22	0.70	0.08
No Presence of Dissolved Oxygen	P05	0.20	0.80	0.00
Temperature of water (Boiling Point)	P06	0.27	0.53	0.20
High Osmotic Pressure	P07	0.56	0.44	0.00
High Conductance	P08	0.80	0.15	0.05
Presence of Chlorine	P09	0.50	0.37	0.13
Results		Might be Pure Water	Pure Water	Not Pure Water

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