CONVENTIONAL SOFT-COMPUTING BASED APPROACH FOR IDENTIFYING SEDIMENTARY ROCK

ISSN: 2141 – 3290

AMADIN, F. I[1] AND OBI, J.C.[2]
[1,2]Department of Computer Science.
University of Benin, Benin City. Nigeria.
frankamadin@uniben.edu[1] and tripplejo2k2@yahoo.com[2]
+234(0)70336633881[1] and +234(0)8093088218[2]

ABSTRACT

Sedimentary rock is an important ingredient in developing numerous human-based components such as limestone for manufacturing cement. Identifying areas that possess these components are sometimes difficult. This paper presents a conventional soft-computing based model for knowledge representation used in identifying sedimentary rock availability. Factors used to identify sedimentary rock on earth surfaces are described in linguistic variables and is used to form this model. The result could be determined in term of "Not Sedimentary rock", "Might be Sedimentary Rock" and "Not Sedimentary Rock" based on the available parameters within a particular region if applied to any region rich in sedimentary rock within Nigeria as opposed to the subjective approach of a particular geologist expert.

INTRODUCTION

Sedimentary rock, rock formed at or near the earth's surface by the accumulation and lithification of sediment (detrital rock) or by the precipitation from solution at normal surface temperatures (chemical rock). Sedimentary rocks are the most common rocks exposed on the earth's surface but are only a minor constituent of the entire crust, which is dominated by igneous and metamorphic rock (Harold and Frederick, 2013). Sedimentary rocks are produced by the weathering of preexisting rocks and the subsequent transportation and deposition of the products. These processes produce soil, unconsolidated rock detritus, and components dissolved in groundwater and runoff.

Sedimentary rocks are produced by cementing, compacting, and otherwise solidifying preexisting unconsolidated sediments. Some varieties of sedimentary rock, however, are precipitated directly into their solid sedimentary form and exhibit no intervening existence as sediment. Organic reefs and bedded evaporites are examples of such rocks. Because the processes of physical (mechanical) weathering and chemical weathering are significantly different, they generate distinct products and two fundamentally different kinds of sediment and sedimentary rock (Andrew, 2013). These include

a. *Terrigenous Clastic Sedimentary Rocks*: These sedimentary rocks consist of rock and mineral grains, or clasts, of varying size, ranging from clay, silt, and sand-up to pebble, cobble and boulder-size materials. These clasts are transported by gravity, mudflows, running water, glaciers, and wind and eventually are deposited in various settings (e.g., in desert dunes, on alluvial fans, across continental shelves, and in river deltas).
b. *Orthochemical Sedimentary Rock*: These sedimentary rocks form by chemical and organic precipitation of the dissolved products of chemical weathering that are removed from the weathering site. Orthochemical sedimentary rocks, such as many limestones, consist of solid precipitated non-detrital fragments that undergo a brief history of transport and abrasion prior to deposition as non-terrigenous clasts. Examples are calcareous or siliceous shell fragments, which are concentrically, layered spherical grains of calcium carbonate. Orthochemical sedimentary rocks, on the other

hand, consist of dissolved constituents that are directly precipitated as solid sedimentary rock and thus do not undergo transportation. Orthochemical sedimentary rocks include some limestones, bedded evaporite deposits of halite, gypsum, and anhydrite, and banded iron formations.

Sedimentary rock or components of sedimentary rock are useful for numerous human endeavors. Subjective approach utilized by geologist in identifying these rock or rocks components are usually tied to imprecise (trial and error) method; methods depending on the head knowledge of the geologist expert on ground and not on any objective (scientific) method that has been developed. The identification of sedimentary rock from a geographical region uses the rich facilities of soft-computing techniques namely; genetic algorithm and fuzzy logic which is usually an objective approach is the bedrock of these research paper.

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" (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

$$[A]^{\gamma} = [a - (1-\gamma)\alpha, b + (1-\gamma)\beta], \forall \gamma \varepsilon [0, 1].$$

The support of A is $(a - \alpha, b + \beta)$.

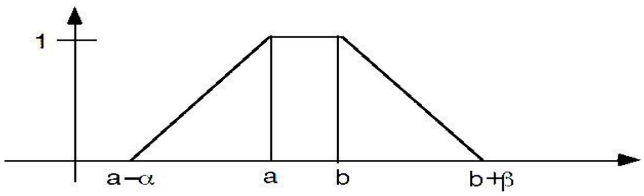

Figure 1: Trapezoidal fuzzy number

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” (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 *et al.*, 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. (Sun and Jang**,** 1993 and Ahmad, 2011) propose an adaptive-network-based fuzzy classifier to solve fuzzy classification problems. 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 lacking of an effective way of defining the boundaries among clusters. This problem becomes more intractable when the number of features used for classification increases (Robert, 2000 and

Kasabov, 1998). A fuzzy set has been derived as an extension of the classical notion of a set. According to classical set theory, an element either belongs or does not belong to the set. In contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set. A membership function can be described as a graph that defines how each point in the input space is mapped to the membership value between 0 and 1. Fuzzy Inference Systems are designed based on the concept of Fuzzy Logic. Fuzzy inference can be defined as the process of formulating the mapping from a given input to an output. A Fuzzy Logic System or a Fuzzy Inference System maps the crisp inputs into crisp outputs. It contains five components: Rule-base, Data-base, Fuzzifier (transformation of crisp values into fuzzy set), Inference and Defuzzifier (transformation of fuzzy set into crisp value).

Factors for Identifying Sedimentary Rock

The properties for identifying sedimentary rock include (Harold and Frederick, 2013):

a. *Crystalline-Texture:* Texture refers to the physical makeup of rock, namely, the size, shape, and arrangement (packing and orientation) of the discrete grains or particles of a sedimentary rock. Two main natural textural groupings exist for sedimentary rocks: fragmental and crystalline. Non-carbonate chemical sedimentary rocks in large part exhibit crystalline texture, with individual mineral grains forming an interlocking arrangement. The size of crystals is controlled to a greater degree by the rate of precipitation, and their texture is modified by post-depositional recrystallization.
b. *Grain Size ranging from 2-256mm:* Particle size is an important textural parameter of clastic rocks because it supplies information on the conditions of transportation, sorting, and deposition of the sediment and provides clues to the events that occurred at the depositional site. Various methods of measuring grain-size distribution have been devised; likewise several different grade-size schemes exist. The size of particulate materials that make up sediments and sedimentary rocks are measured by determining the rate at which particles of varying diameter accumulate in a water-filled glass. Rock size ranging from 2-256mm are most like sedimentary rock.
c. *Particle shape:* Three different but related properties determine particle shape: form, roundness, and surface texture. Particle form is the overall shape of particles, typically defined in terms of the relative lengths of the longest, shortest, and intermediate axes. Particles can be spherical, prismatic, or bladelike. Roundness or angularity is a measure of the smoothness of particles. Surface texture is the presence or absence of small, variously shaped markings that may occur on grain surfaces.
d. *Porous-Permeable Fabric:* The fabric of a sedimentary rock controls the rock's porosity and permeability. The orientation, or lack thereof, of the crystals or grains that make up a sedimentary rock constitutes one aspect of fabric. Genetically, there are two principal varieties of oriented fabrics: primary (or depositional) and secondary (or deformational).
e. *Detrital-authigenic composition:* Minerals that make up sedimentary rocks are of two principal types namely, detrital and authigenic. Detrital minerals, such as grains of quartz and feldspar, survive weathering and are transported to the depositional site as clasts. Authigenic minerals, like calcite, halite, and gypsum, form in situ within the depositional site in response to geochemical processes.
f. *3-demension rock structures:* Sedimentary structures are the larger, generally three-dimensional physical features of sedimentary rocks; they are best seen in outcrop or in large hand specimens rather than through a microscope. Sedimentary structures include features like bedding, ripple marks, fossil tracks and trails, and mud cracks. They conventionally are subdivided into categories based on mode of genesis.
g. *Natural occurring Sedimentary environment:* is the specific depositional setting of a particular sedimentary rock and is unique in terms of physical, chemical, and biological characteristics.

METHODOLOGY

In other to achieve our underlining objectives, the under listed criteria were applied in designing the proposed soft-computing model.

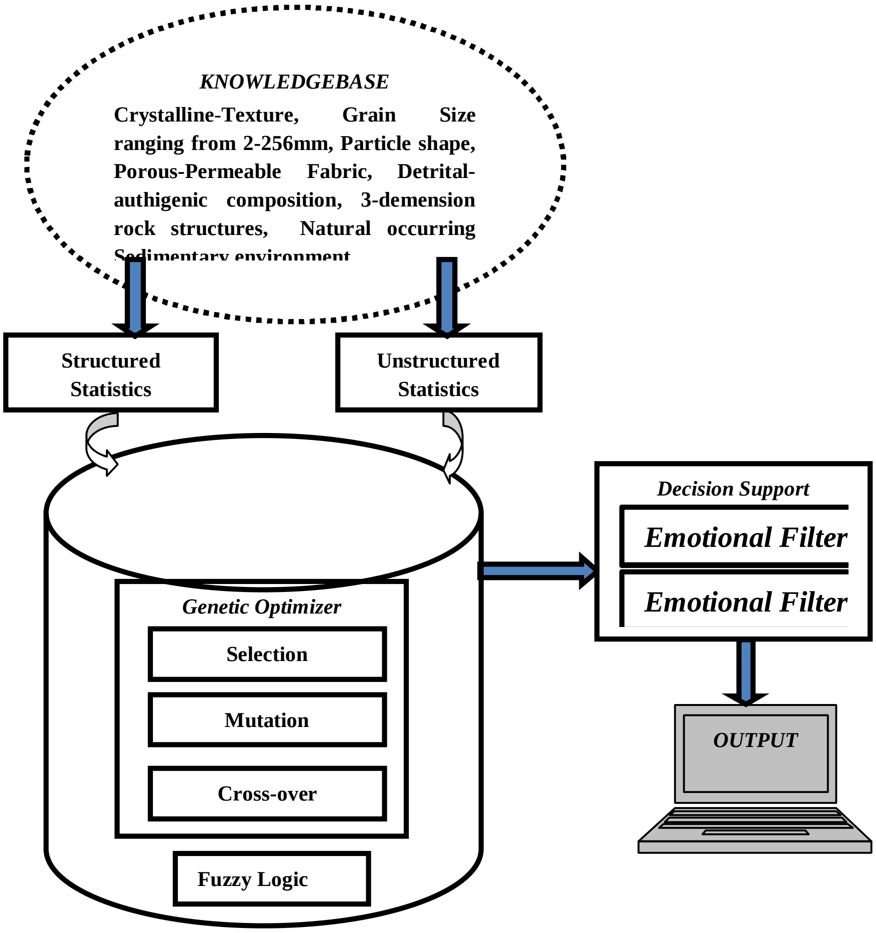

Figure 2: Soft-computing Model for Identifying Sedimentary Rock

The model pictorially illustrated in Fig.2, comprises certain features, which includes

- ***a.*** *Knowledge base:* A varid form of database that hold special information. The criteria (parameters or fuzzyset) for determinimg sedimentary rock is held in the knowledgebase.
- ***b.*** The structured and unstructures statistic simply refer to database information (usually well arranged) and dispered information residing in the knowledge-base respectively.
- ***c.*** The *Genetic Optimizer* handles membership optimization following the procedure specified within the architecture.
- ***d.*** *Fuzzy Logic:* the impreciseness (vagueness) associated with the parameters for identifying sedimentary rock where handled utilizing fuzzy-if-then rules.
- ***e.*** *Decision support:* predicate output result based on emotional filter and cognitive filter. The cognitive filter of the decision support engine takes as input the output report of knowledge base and applies objective rules to rank the hospital locations. The emotional filter takes as input the output report of the cognitive filter and applies the subjective rules in the domain of studies in order to rank the sedimentary rock.
- ***f.*** *The stationery system:* produces the output based on the paramters received.

RESULT AND DISCUSSIONS

The fuzzy partition for each input feature consists of the parameters for identifying sedimentary rock. However, it can occur that if the fuzzy partition for identifying sedimentary rock 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 for identifying sedimentary uses the parameters specified above:

a. Not Sedimentary Rock (Class: C_1)
b. Might been Sedimentary Rock (Class: C_2)
c. Sedimentary Rock (Class: C_3)

If the assessed region ***(***such Cross Rivers, Ogun, Benue, Gombe, Ebonyi, Kogi, Osun, Ekiti, Kwara and Cross Rivers all within Nigeria***)*** possesses less than or equal to two of the parameters for identifying sedimentary rock *THEN* (C_1), if the assessed region/environment possesses three of the parameters for identifying sedimentary rock THEN (C_2) and if the assessed region/environment possesses four or more parameters for identifying sedimentary rock (*THEN* (C_3).

The Fuzzy IF-THEN Rules (R_i) for identifying sedimentary rock:

R1: IF the region is possesses crystalline-texture THEN it is in class C_1.

R2: IF the region is possesses crystalline-texture and grain size ranging from 2-256mm *THEN* it is in class C_1.

R3: IF the region is possesses crystalline-texture, grain size ranging from 2-256mm and particle shape *THEN* it is in class $C_{2.}$

R4: IF the region is possesses crystalline-texture, grain size ranging from 2-256mm, particle shape, porous-permeable fabric *THEN* it is in class $C_{3.}$

R5: IF the region is possesses crystalline-texture, grain size ranging from 2-256mm, particle shape, porous-permeable fabric and detrital-authigenic composition *THEN* it is in class $C_{3.}$

R6: IF the region is possesses crystalline-texture, grain size ranging from 2-256mm, particle shape, porous-permeable fabric, detrital-authigenic composition and 3-demension rock structures *THEN* it is in class C_3

R7: IF the region is possesses crystalline-texture, grain size ranging from 2-256mm, particle shape, porous-permeable fabric, detrital-authigenic composition, 3-demension rock structures and natural occurring sedimentary environment *THEN* it is in class $C_{3.}$

A typical data set that contains the seven parameters is presented in Table 1. This shows the degree of intensity (membership) for identifying sedimentary environment.

Table 1: Data Set showing the Degree of membership for identifying sedimentary environment

Parameters or Fuzzy sets For Identifying Sedimentary Rock	Codes	Membership Function for Identifying Sedimentary Environment		
		Cluster 1 (C_1)	Cluster 2 (C_2)	Cluster 3 (C_3)
Crystalline-texture	R01	0.50	0.15	0.35
Grain size ranging from 2-256mm	R02	0.20	0.20	0.60
Particle shape	R03	0.10	0.80	0.10
Porous-permeable fabric	R04	0.20	0.10	0.70
detrital-authigenic composition	R05	0.30	0.60	0.10
3-demension rock structures	R06	0.05	0.05	0.90
Natural occurring sedimentary environment	R07	0.00	0.50	0.50

The algorithm terminates when the stop criterion is met. The Genetic algorithm utilizes the following conditions to determine when to stop: Generations or Fitness limit. In this case, we used the number of generation (4^{th} generation) to determine the stopping criterion.

Genetic Algorithm Inference:

R1: IF R01 THEN C1 = 0.50
R2: IF R01 AND R02 THEN C2 = 0.18
R3: IF R01, R02 AND R03 THEN C2 = 0.38
R4: IF R01, R02, R03 AND R04 THEN C3 = 0.44
R5: IF R01, R02, R03, R04 AND R05 THEN C3 = 0.37
R6: IF R01, R02, R03, R04, R05 AND R06 THEN C3 = 0.46
R7: IF R01, R02, R03, R04, R05, R06 AND RO7 THEN C3 = 0.46

We then convert these resolved values into whole numbers and imply them to be the fitness function (*f*) of the initial generation (Parents) as shown in Table 2.

R1: 50, R2: 18, R3: 38 R4: 44 R5: 37 R6: 46 R7: 46

Table 2: 1^{st} and 2^{nd} Generation Table

S/N	Selection	Chromosomes (Binary; 0 or 1)			Fitness function
		Parent (1^{st} Gen)	Crossover	Parent (2^{nd} Gen)	
1	50	110010	1 & 6	110101	53
2	46	101110	2 & 4	101100	44
3	46	101110	Mutation	101100	44
4	44	101100	2 & 4	101110	46
5	38	100110	5 & 7	100010	34
6	37	100101	1 & 6	100010	34
7	18	010010	5 & 7	010110	22

To create our 2^{nd} and 3^{rd} generation from the parents (1^{st} generation) we chose the third bit from the left to be our crossover point. In the 4^{th} generation each bold bit signifies the cross-over bits, a single bold bit signifies mutation of that bit and an italicized chromosomes signifies elitism. See Tables 3 and 4.

Table 3: 2^{nd} and 3^{rd}Generation Table

S/N	Selection	Chromosomes (Binary; 0 or 1)			Fitness function
		Parent (2^{nd} Gen)	Crossover	Parent (3^{rd} Gen)	
1	53	110101	1 & 3	110100	52
2	46	101110	2 & 6	101010	42
3	44	101100	1 & 3	101101	45
4	44	101100	4 & 5	101010	42
5	34	100010	4 & 5	100100	36
6	34	100010	2 & 6	100110	38
7	22	010110	Mutation	010100	20

Table 4: $3^{rd}$and 4^{th} Generation Table

S/N	Selection	Chromosomes (Binary; 0 or 1)			Fitness function
		Parent (3^{rd} Gen)	Crossover	Parent (4^{th} Gen)	
1	52	110100	Mutation	110110	54
2	45	101101	2 & 3	101110	46
3	42	101010	2 & 3	101001	41
4	42	101010	6 & 4	101000	40
5	38	100110	5 & 7	100100	40
6	36	100100	6 & 4	100110	38
7	20	010100	5 & 7	010110	22

The best fourth generation (stopping criterion) is that with the best fitness function, 54. This implies that the clusters of the various parameters has been searched and optimized to 0.54, serving as the boundary in determining high and low degree of intensity of the served membership function. Therefore any parameter(s) with membership function (MF > 0.50) implies high degree of membership and any parameters(s) with membership function (MF < 0.50) implies low degree of membership.

Based on the optimized membership function, the result in table 5 is obtained.

Table 5: Data Set showing the Degree of membership for Programming Language reliability

Parameters or Fuzzy sets For Identifying Sedimentary Rock	Codes	Membership Function for Identifying Sedimentary Environment		
		Cluster 1 (C_1)	Cluster 2 (C_2)	Cluster 3 (C_3)
Crystalline-texture	R01	0.50	0.15	0.35
Grain size ranging from 2-256mm	R02	0.20	0.20	0.60
Particle shape	R03	0.10	0.80	0.10
Porous-permeable fabric	R04	0.20	0.10	0.70
detrital-authigenic composition	R05	0.30	0.60	0.10
3-demension rock structures	R06	0.05	0.05	0.90
Natural occurring sedimentary environment	R07	0.00	0.50	0.50
Result		Not Sedimentary Rock	Might been Sedimentary Rock	Sedimentary Rock

CONCLUSION

The ability in determining if certain area possesses sedimentary rock can be difficult if observed subjectively. The needs to design a system that would assist geologist in determining if a certain geographical region possesses the criteria/parameters for determining sedimentary rock availability cannot be over emphasized. The practicality of genetic algorithm and fuzzy logic (Genetic-fuzzy system) has been demonstrated by our proposed model utilizing the genetic inference and the fuzzy-if-then rules on page 9 and 10 respectively. This model which uses a set of fuzzified data set incorporated into genetic algorithm system is more precise than the traditional system for recognizing the aforementioned problem.

REFERENCES

Ahmad H. (2011), Fuzzy *Approach to Likert Spectrum in Classified Levels in Surveying Researches Retrieved* http://www.tjmcs.com.

Andrew A. (2013), *About Sedimentary Rocks* Retrieved from http:// geology.about.com/cs/basic-roxmin/a/aa011804b.htm

Angel C. and Rocio R. (2011), *Documentation management with Ant colony Optimization Metaheuristic: A Fuzzy Text Clustering Approach Using Pheromone trail.* Retrieved from soft computing in Industrial applications, Advances in intelligent and soft Computing, vol. 96, 2011, 261-70, DOI: 10.1007/978-3-642-20505-1_23

Harold J. B. and Frederick L. S. (2013), *Properties of Sedimentary Rock.* Retrieved online from http//: britannica.com/EBchecked/topic/532232/sedimentary.

Kasabov N. K. (1998), *Foundations of Neural Networks, Fuzzy Systems and Knowledge Engineering*, A Bradford Book, The MIT Press Cambridge, Massachusetts London, England, ISBN 0-262-11212-.

Kuang Y. H.; Ting-H. C. and Ting-Cheng Chang (2011), *Determination of the Threshold Value B Of Variable Precision Rough set By Fuzzy Algorithms*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0888613X11000831

Leondes C. (2010), "*The Technology of Fuzzy Logic Algorithm*. Retrieved from Suite101.com/examples-of-expert-System-application-in-artificial Intelligence.

Robert F. (2000), "*Introduction to Neuro-Fuzzy Systems, Advances in Soft Computing Series*, Springer-Verlag, Berlin/Heildelberg, 289 pages. (ISBN3-7908-1256-0)(MR1760972.

Rudolf K. (2008), *Neuro-fuzzy Systems.* Retrieved from http://ask.com

Sun C.T. and Jang J.S. (1993) "A neuro-fuzzy classifier and its applications", In: *Proc. IEEE Int. Conference on Neural Networks, San Francisco*, pp.94–98.

Zadeh L.A. (1965), "*Fuzzy sets. Information and Control*", 8 pp.338-353.