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Fuzzy Classifier Approach in Classifying Secondary Stage of Syphilis

Okengwu U.A[1]. And Ejiofor C. I[2]
Department of Computer Science, University of Port-Harcourt, Port-Harcourt. Nigeria [1,2].
Corresponding Author: Okengwu U.A1.

Abstract: *The bacterium treponema pallidum, which is a subspecie of pallidum, is the primary cause of syphilis. Syphilis is a contagious disease which is mostly transmitted through sex either anal or oral sex. The approach on ground of the classification of syphilis is too precise proving a sharp contraction between bondaries. In addressing this precise approach a fuzzy approach was adopted to provide non-precise boundaries overlapping classes in classifying Secondary syphilis into "Mild", "Moderate" and Severe". This approach is objective with the aim of quick and objective recognition, based on available objective decision variables, parameters or criteria.*

Keywords: *Fuzzy Classifier, Fuzzy Logic, Fuzzy Cluster, Syphilis, Set theory*

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I. Background

The bacterium treponema pallidum, which is a subspecies of pallidum (CDC, 2015) causes syphilis. Syphilis is a contagious disease; transmitted through anal or oral sex intercourse (CDC, 2015). Body contact has also provided an avenue in contacting syphilis such as; prolong kissing (MedicineNet, 2016). These bacteria use an individual body sore as host. Most infected persons are usually unaware of this illness (MedicineNet, 2016).

Syphilis can be categorized into four main stages: Early or primary syphilis, Secondary stage, Latent syphilis and Tertiary syphilis (MedicineNet, 2016 and Franzen, 2008).

Infected individual experiencing early or primary syphilis will develop one or more sores which are usually small and painless. These ulcers develop between 10 – 90days of exposure and have the propensity of self-healing within six weeks (Healthline, 2016 and medicineNet, 2016).

The secondary stage of syphilis may last one to three month of initial contact and begin within six weeks to nine months of exposure. Individuals with this kind of syphilis exhibit; rash on single or both palm of their hand or on the soles of their legs, they may also experience moist warts in the groin, white patches on the inside of the mouth, swollen lymph glands, fever and weight loss. Like primary syphilis, secondary syphilis can be resolved without treatment (Healthline, 2016 and MedicineNet, 2016). Latent syphilis is a dormant (inactive) form of syphilis, causing no noticeable symptoms (Healthline, 2016 and MedicineNet, 2016). Tertiary syphilis is the advance form of syphilis which if left untreated causes severe problems within the heart, brain, and nerves that can result in paralysis, blindness, dementia, deafness, impotence, and even death if it's not treated (Healthline, 2016 and MedicineNet, 2016). The risk of syphilis can be decreased by latex condom use, or not having sex (Newman et al., 2015) Syphilis can be effectively treated with antibiotics. The preferred antibiotic for most cases is benzathine penicillin G injected into a muscle (Wood, 2009). The sign and symptoms of syphilis depend on the stages of occurrences (CDC, 2015, MedicineNEt, 2016 and Healthline, 2016): Primary syphilis usually is tied to: skin ulcers, and non-itchy of ulcers. Secondary syphilis usually are tied to palm rash, sole rash, fever, headache, weight loss, muscle ache and fatigue. Latent syphilis usually exhibits no symptom. Tertiary syphilis is usually tied to non-cancerous growth, pain of the chest, severe headache, paralysis, numbness, dementia, and blindness. The classification of varied forms of secondary syphilis, using fuzzy based approaches (Fuzzy rule and Fuzzy Algorithm) is the intent of this research paper. The proper classification, overlapping sign and symptoms usually are issues with syphilis classification. Based on the aforementioned hindrance the actualization of this research paper was inspired.

II. Review of Methodology

Fuzzy sets were introduced by Zadeh in 1965 to represent, manipulate data and information processesing with 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" (Kasabov 1998; Robert 2000; Christos and Dimitros 2008).

Fuzzy classification assumes the boundary between two neighboring classes as a continuous, overlapping area within which an object has partial membership in each class. It reflects the reality of many applications in which categories have fuzzy boundaries, and also provides a simple representation of the potentially complex partition of the feature space. Sun and Jang (1993) 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 inabilities in defining the boundaries among clusters. This problem becomes more intractable when the number of features used for classification increases (Robert, 2000, Kasabov and Nikola 1998, Rudolf, 2008, Christos and Dimitros, 2008). Therefore fuzzy approach is a clustering problem, which involves the task of dividing data points into homogeneous classes or clusters so that items in the same class are as similar as possible and items in different classes are as dissimilar as possible (Jiang 1994; Babuska, 1998 Osama 2008 and Rudolf et al. 2008). Fuzzy classifier is a clustering approach build on the premise of fuzzy logic and fuzzy rules. A Fuzzy classifier is an algorithm that assigns a class label to an object, based on the object description. It is also said that the classifier *predicts* the class label (Angelov and Zhou, 2004). The object description comes in the form of a vector containing values of the features (attributes) deemed to be relevant for the classification task (Ishibuchi et al., 1995). Typically, the classifier learns to predict class labels using a training algorithm and a training data set. When a training data set is not available, a classifier can be designed from prior knowledge and expertise. Once trained, the classifier is ready for operation on unseen objects (Cordon et al., 1999). The simplest fuzzy rule-based classifier is a fuzzy if-then system.

III. Methodology Application

The methodology adopted in this research paper is geared towards specifying fuzzy logic application, utilizing fuzzy set theory and fuzzy rule and associated fuzzy algorithm for the classification of secondary syphilis. The conventional criteria and diagnostic rules used in hospital were obtained and adopted. These criteria (c: signs and symptoms) includes: palm rash, sole rash, fever, headache, weight loss, muscle ache and fatigue (SS). These criteria were tied to two predominate conventional rules:

Rule 1: If a patient is experiencing three or more of the under-listed criteria THEN Syphilis present.

Rule 2: If a patient is experiencing less than three of the under-listed criteria THEN Syphilis not present.

Table 3.1: captures synthesis data pertaining to five (05) patients. The criteria are tied to a symptoms score ranging from (0 – 10) with a score of 5 and above seen as selective while less than 5 is seen as non-selective.

Table 3.1: Synthesize data for Syphilis

Cases	Palm rash	Sole rash	Fever	Headache	Weight Loss	Muscle Ache	Fatigue	Diagnosis
Case 1	5	3	-	-	-	-	-	Not Syphilis
Case 2	6	4	5	-	-	-	-	Not Syphilis
Case 3	5	2	7	8	-	-	-	Syphilis
Case 4	5	6	7	5	5	5	-	Syphilis
Case 5	5	7	8	7	9	6	5	Syphilis

The application of fuzzy logic will re-categorize this data through the application of fuzzy membership function (fuzzification). The application of Generalized Bell Membership Function (GBMF) was identified as most appropriate due to its simplicity in specifying linguistic values (Mild, Moderate and severe). Equation 3.1 capture this formula

$$u\,(x) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}} \quad . \quad . \quad . \quad (3.1)$$

$Where$:

$a = the\ mean\ of\ parameter\ values$

$b = known\ as\ the\ bias, controls\ the\ slope\ of\ the\ curve\ of\ x\ at\ -b/2a, c-a, a, b/2a$

$c = centre\ of\ the\ curve$

$x = case\ fuzzy\ set\ decision\ variables\ values$

$The\ parameters\ a, b, and\ c\ are\ referred\ to\ as\ premise\ or\ activation\ parameters.$

The range of possible memberships specified by the GBMF input space is captured in Equation (3.2).

$$\mu(x) = \begin{cases} \text{if } x \leq 0.29, \text{ Mild} \\ \text{if } 0.30 \leq x \leq 0.60, \text{ Moderate} \\ \text{if } 0.61 \leq \text{x} \leq 1.0, \text{ Severe} \end{cases} \quad . \quad . \quad . \quad (3.2)$$

Applying Equation 3.1, the fuzzified values on Table 3.2 are generated

Table 3.2: Fuzzified Synthesize data for Syphilis

Cases	Palm rash	Sole rash	Fever	Headache	Weight Loss	Muscle Ache	Fatigue
Case 1	0.57	0.22	-	-	-	-	-
Case 2	0.47	0.61	0.69	-	-	-	-
Case 3	0.57	0.89	0.52	0.44	-	-	-
Case 4	0.52	0.39	0.52	0.69	0.70	0.60	-
Case 5	0.52	0.31	0.44	0.03	0.40	0.5	0.55
A=	5.2	4.4	6.75	6.66	7.0	5.5	5.0

Applying Equation 3.2, the fuzzified linguistic values on Table 3.3 are generated

Table 3.3: Fuzzified Synthesize Linguistic data Values for Syphilis

Case Code	Cases	Palm rash	Sole rash	Fever	Headache	Weight Loss	Muscle Ache	Fatigue
P01	Case 1	Moderate	Mild	-	-	-	-	-
P02	Case 2	Moderate	Severe	Severe	-	-	-	-
P03	Case 3	Moderate	Severe	Moderate	Moderate	-	-	-
P04	Case 4	Moderate	Moderate	Moderate	Severe	Severe	Moderate	-
P05	Case 5	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
	A=	Moderate	Moderate	Severe	Severe	Severe	Moderate	Moderate

The data captured on Table 3.3 is used in combination with the conventional diagnostic rule for the classification syphilis using fuzzy-based rules. The obtained crisp values (non-fuzzy) values have been extended to accommodate fuzzy set values (mild, moderate and severe) which invariably produces new fuzzy rules (combining case code, membership and classes):

RULE 1: If a patient exhibits three or less (C ≤ 3) of the criteria for syphilis with moderate or severe occurrence THEN Mild Syphilis Present.
RULE 2: If a patient exhibits four (C = 4) of the criteria for syphilis with moderate or severe occurrence THEN Moderate Syphilis Present.
RULE 3: If a patient exhibits four (C ≥ 4) of the criteria for syphilis with moderate or severe occurrence THEN Severe Syphilis Present.

By permutation (3^5), taking cognizant of criteria and membership, we have 245 rules
These rules are formulated using fuzzy set theory. In set theory a union (denoted by ∪) is the set of all distinct elements in the collection. It is one of the fundamental operations through which sets can be combined and related to each other. The initial ∪ is initialized as P ∪ ∅ = P, for the set P. Therefore the fuzzy set rules are thus:

P0: P ∪ ∅
P01: {∅ ∪ Palm rash (mild)} = Mild Secondary Syphilis.
P02: {∅ ∪ Palm rash (mild)} ∪ Sole rash (severe) = Mild Secondary Syphilis Absent.
P03: {∅ ∪ Palm rash (Mild) ∪ Sole rash (mild)} ∪ Fever (severe) = Mild Secondary Syphilis Present.
P04: {∅ ∪ Palm rash (severe) ∪ Sole rash (severe) ∪ Fever (mild)} ∪ Headache (severe) = Moderate Secondary Syphilis Present.
P05: {∅ ∪ Palm rash (moderate) ∪ Sole rash (moderate) ∪ Fever (moderate) ∪ Headache (severe)} ∪ Weight Loss (severe) = Severe Secondary Syphilis Present.
P06: {∅ ∪ Palm rash (severe) ∪ Sole rash (severe) ∪ Fever (severe) ∪ Headache (severe) ∪ Weight Loss (moderate)} ∪ Muscle ach (moderate) = Severe Secondary Syphilis Present.
P07: {∅ ∪ Palm rash (mild) ∪ Sole rash (moderate) ∪ Fever (moderate) ∪ Headache (severe) ∪ Weight Loss (severe) ∪ Muscle ache (severe)} ∪ Fatigue (severe) = Severe Secondary Syphilis Present.
These rules are used in producing a simplified fuzzy based Algorithm. The Fuzzy Algorithm imbibes artificial intelligence techniques in tying the symptoms of syphilis to the differential diagnosis of three classes of secondary stage syphilis. The Algorithm is depicted on Figure 3.1
INPUT:

Types of Secondary Syphilis (Secondary Syphilis; Mild, Moderate, Severe)
No. of Symptoms (P)1, P)2… Pn) = 7

P; Fuzzy parameters (Symptoms Codes)
Fuzzy predefined Rules

More than five symptoms = Severe syphilis Present
Exactly four symptoms = Moderate Syphilis Present
Three symptoms and below = Mild Syphilis present

// INITIALIZATION
1. Randomly pick a patient *K;*
2. Save identification (diagnosis) Result in *Knot;*

// Loop till terminal point
3. For P = 1 to n do;

// *MILD SECONDARY SYPHILIS*
4. Diagnose Mild Syphilis;
5. If Mild Syphilis symptoms P01, P02 THEN Mild Syphilis;
6. Else if
7. Might be Moderate Secondary Syphilis; (*exhibiting three or four symptoms of Syphilis)*
8. Else
9. Not Syphilis;

// *MODERATE SECONDARY SYPHILIS*
10. Diagnose for Moderate Syphilis;
11. If Moderate Syphilis symptoms P01, P02, P03, P04 THEN Moderate Syphilis
12. Else if
13. Might be Severe Secondary Syphilis;; (*exhibiting more than four symptoms)*
14. Else
15. Not Syphilis;

// *SEVERE SECONDARY SYPHILIS*
16. Diagnose for Severe Syphilis;
17. If Severe Syphilis symptoms P01, P02, P03, P04, P05, P06, P07 THEN Severe Syphilis;
18. Else if (*exhibiting less than seven*)
19. Might be Other form of syphilis ;
20. Else
21. Not Syphilis;

//Save results in *Knot;*
22. Return diabetes result for patient K

Figure 3.1: Fuzzy Classifier Algorithm

IV. Simulation Result

The simulation result provides a graphical description pertaining to the linguistic values for classifying syphilis. These values produce the degree of membership of each criterion to a particular case. Table 3.4, captures class classification which is exemplified graphically on Figure 3.2

Table 3.4: Class classification of Syphilis

Case Code	Cases	Palm rash	Sole rash	Fever	Headache	Weight Loss	Muscle Ache	Fatigue	Syphilis Classification
		Membership Values tied to each Criteria							
P01	Case 1	0.57	0.22	-	-	-	-	-	Mild
P02	Case 2	0.47	0.61	0.69	-	-	-	-	Mild
P03	Case 3	0.57	0.89	0.52	0.44	-	-	-	Moderate
P04	Case 4	0.52	0.39	0.52	0.69	0.70	0.60	-	Severe
P05	Case 5	0.52	0.31	0.44	0.03	0.40	0.5	0.55	Severe
A=		5.2	4.4	6.75	6.66	7.0	5.5	5.0	Severe

Table 3.4, represents the degree of membership function for syphilis criteria, for instance, P01 in column 1 and 2, we notice it has 0.57 and 0.22. In percentage, it can be represented as 57% that is 57% of the palm rash (criteria of syphilis) and 22% of sole rash has contributed to mild classification of syphilis. This means that the degree of membership function of P01 matches **0.50 and 0.20 of the fuzzy scaled ranged.** The Fuzzy clustering graphical distribution shown Figure 3.2, depicts Twenty (20) linguistic values with "Moderate", one (1) linguistic values with "Mild" and eight (08) linguistic values "Severe".

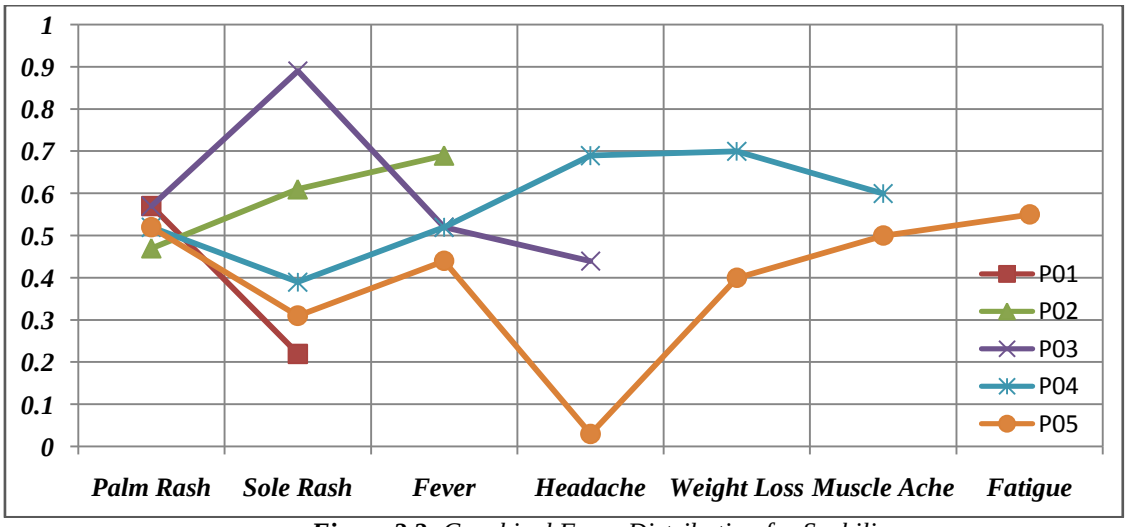

Figure 3.2: *Graphical Fuzzy Distribution for Syphilis*

V. Discussion

The application of fuzzy set, fuzzy linguistic variables, fuzzy linguistic values, Fuzzy rules and fuzzy algorithm for the classification of secondary stage syphilis has been the focal point of this research paper. The appropriate and exhibited decision variable (signs and symptoms) has been captured using the aforementioned fuzzy components. The robustness of this approach has been exemplified compared to the restrictive conventional approaches. This approach is cost-effective in terms of time and cost, enhancing prompt and accurate classification.

VI. Conclusion

A multivalent approach for the classification of secondary stage syphilis has been provided with the rich facilities of fuzzy logic; which was captured from the perspective of fuzzy rule and fuzzy classifier algorithm. This approach provides three boundaries of classifications: "Mild", "Moderate" and "Severe" as opposed to the conventional approaches tied to it restrictiveness. The cost–effectiveness of this approach will go a long way in assisting physician in ascertaining prompt and quick classification.

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