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APPLICATION OF FUZZY LOGIC IN POULTRY DISEASES MANAGEMENT

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ABSTRACT

Poultry constitutes the largest group of livestock that are kept all over the world. They play an important role in poverty alleviation and food security. Unfortunately, the existing veterinary clinics especially in Nigeria are not sufficient to provide the needed services in the management of poultry diseases. In this paper, an alternative strategy is provided by developing models for assessing the severity and management of some poultry diseases using Fuzzy cognitive maps.

Keywords: Poultry, Fuzzy Cognitive Maps and Expert systems

INTRODUCTION

Poultry is the term used to describe a group of birds kept for meat and eggs (example chicken) or reared for a useful purpose (example pheasants) (Adebiyi, et al., 2020). They are one of the cheapest sources of meat and can be kept by anyone. They can be kept by large commercial farmers, by smaller farmers and by households (Abraham and Nath, 2000).

In developing countries like Nigeria, many people living in the rural areas are poultry farmers, they keep small flocks of scavenging poultry. Chickens are predominantly kept by these farmers and they play an important role in poverty alleviation and food security (Aldobrandine, 2016; Aillo, 2016). Though they are kept in small quantities, they help in providing meat and eggs for family consumption, for sale to provide additional income and many other social functions. Poultry disease for a long time now has been one of the main problems disturbing our poultry industry development (Archie et al., 2006; Siswoyo et al., 2020). It has become the limiting factor in the development of poultry industry.

There are many poultry farms across Nigerian villages. Unfortunately, the existing veterinary clinics are not sufficient to provide the needed services in the management of poultry diseases. It is imperative to integrate veterinary services with developments in other fields to enhance the growth of poultry industry and overcome poultry diseases problems. Hence, the need for a web-based computer program that is critical in the management of poultry diseases. This forms the basis for initiating an alternative strategy by developing models for assessing the severity and management of some poultry diseases.

METHODS

The algorithm for the fuzzy diagnostic process of poultry farm diseases is shown as follows:

Let ***D*** denotes the number of poultry farm diseases, $D = \left(d_1, d_2, d_3, d_4\right)$, whereby $d_i \in D$, represents the set of all possible diseases.

Let:

$M_{InitialWeight}$	represents the Initial Weight Matrix
$M_{OverallWeight}$	represents the Overall Weight Matrix
L_{Option}	represents the Linguistic Option selected.
T_{Option}	represents the Total Linguistic Options for a particular concept.
$V_{Initial}$	represents the Initial State Vector (Input Vector)
V_{New}	represents the New State Vector
V_{Final}	represents the Final State Vector (Decision Output Vector)
f	represents Sigmoid Function

Step 1: For all ***N*** Domain Experts, read inputs and output parameters for ***d.***

(a) Determine the numbers of linguistic variables associated with each input/output parameter and select an appropriate membership function (Triangular, Trapezoidal, Sigmoid and Gaussian).

(b) Determine all the fuzzy sets for the system.

Step 2: Generate fuzzy rules from the data.

Step 3: For all ***N*** Domain Expert, interrelationships between concepts are determined and an initial FCM based on individual expert judgment is developed.

Step 4: For all ***N*** Domain Experts, an Initial Weight Matrix $M_{InitialWeight}$ is computed and an Overall Weight Matrix $M_{OverallWeight}$ is computed as:

$$M_{OverallWeight} = f\left(\sum_{i=1}^{n}(M_{InitiiaIWeight})_i\right)$$

where n is the total number of initial weight matrixes.

Step 5: Construction of an augmented FCM.

Step 6: Initialization the FCM model:

Initialize $M_{OverallWeight}$ to Input Pattern.

Initialize $V_{Initial}$ (Input Vector) to Input Pattern.

Compute $V_{Initial}$: (using data transformation formula)

$$V_{Initial} = \frac{L_{Option}}{\sum_{j=1}^{m}(T_{Option} - 1)_j}$$ where m is the total number of linguistic concepts.

While the system has not converged, Do steps 7 and 8 for each Input Vector by iteration.

Step 7: Compute V_{new}:

$$V_{new} = f(V_{Initial} * M_{OverallWeight})$$

Step 8: Get Output Pattern: Threshold and Update the resultant state vector.

$$V_{New+1} = f(V_{New} + V_{New} * M_{OverallWeight})$$
$$V_{New+2} = f(V_{New+1} + V_{New+1} * M_{OverallWeight})$$
$$V_{New+3} = f(V_{New+2} + V_{New+2} * M_{OverallWeight})$$
$$V_{New+4} = f(V_{New+3} + V_{New+3} * M_{OverallWeight})$$
$$V_{New+n} = f(V_{New-1} + V_{New-1} * M_{OverallWeight})$$

Step 9: Repeat steps 7 and 8 until equilibrium is attained and the values of all the concepts no longer change. At this step, the system converges and the final value V_{Final} is gotten.

The flow diagram for the fuzzy diagnostic algorithm is shown in Figure 1

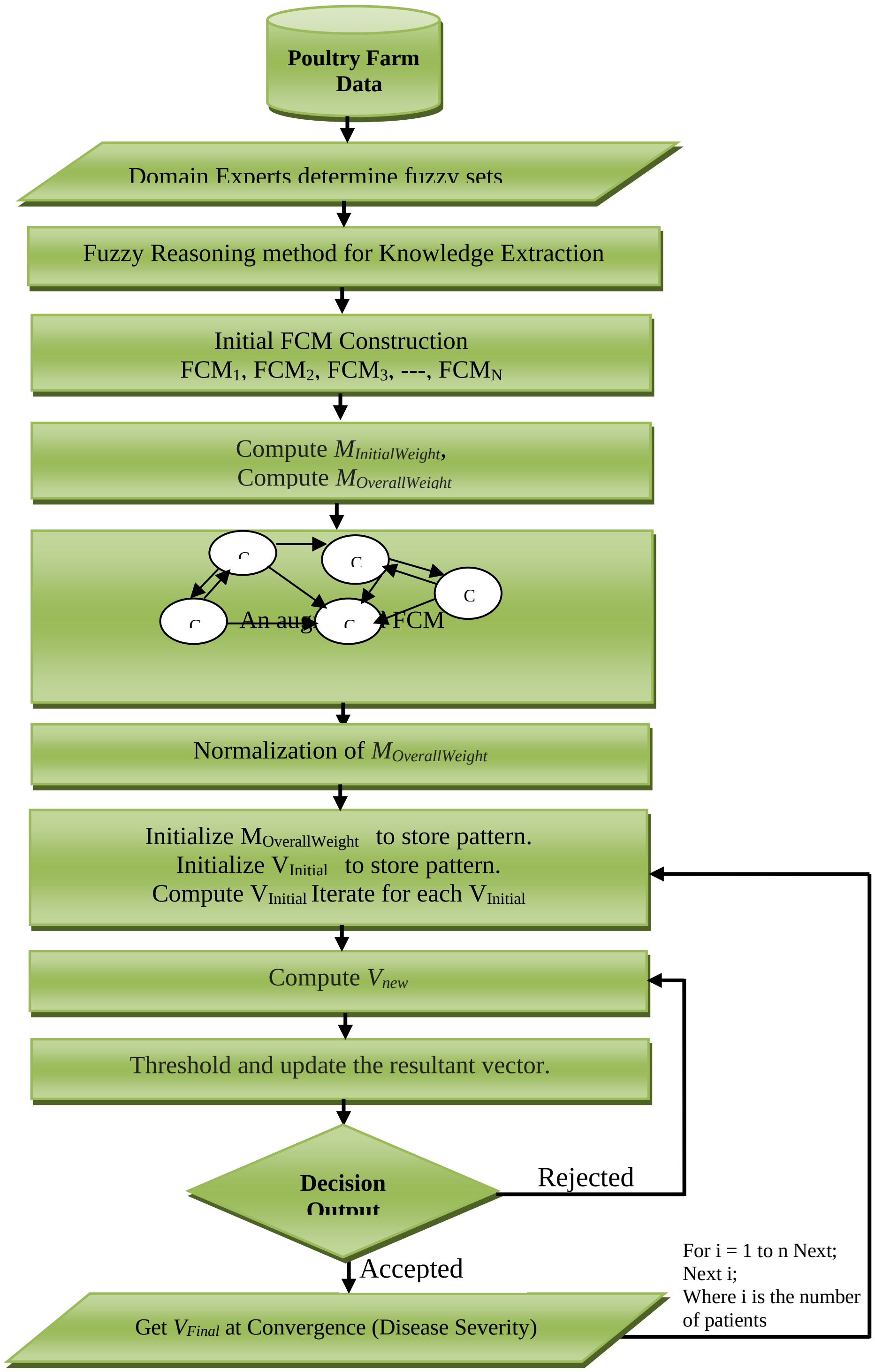

Figure 1: Flow Diagram of the Fuzzy Diagnostic Algorithm

Threshold Function

Several formulae can be used as the threshold function in a FCM system. The threshold function is used to reduce unbounded weight sum to a certain range. The logistic Signal Function (Sigmoid Function) *f*, is a threshold function used in this research for two reasons:

i.) To normalize linguistic weights in the interval [-1,1].
ii.) To normalize concepts' values in the interval [0,1]

The logistic sigmoid function is a continuous function and provides true fuzzy conceptual node states. The sigmoid function is:

$$f(x) = \frac{1}{(1 + e^{-cx})}$$

The constant, c, is critical in determining the degree of fuzzification of the function; the various values of c are 1, 2, 5 and 10 as established in literature and are shown in Figure 2. We have chosen c = 1 as a trade-off which favors the fuzzy interval [0, 1] in this study. Plots of this threshold function for various values of the constant c are generated.

Model Development for Assessing the Severity of Poultry Diseases

FCM is a suitable technique to cope with complex decision-making tasks in issues of uncertainty such as the severity of poultry diseases, predicting treatment outcome and therapy plan acceptance. The combination of inadequate expertise and sometimes non-specific symptomatology that characterizes poultry diseases exponentially increases the morbidity and mortality rates. In view of this, a diagnostic tool was developed whereby seasoned veterinary medical experts were incorporated to assist in the development of the logical model for effective poultry farm management.

The developed method based on FCMs for assessing the severity of poultry farm diseases is a framework within which Veterinary Physicians evaluate a series of traditional diagnostics concepts (Symptoms, Sign, Laboratory Tests, and other factors) using fuzzy concepts to manage medical uncertainty. The way the FCM models were designed increased the objectivity of the diagnostic process by taking into account the different Veterinary Physicians' opinions regarding the interplay of decision concepts.

FCM models for the chosen four poultry diseases: Gumboro and Fowl Typhoid Fever. Three Veterinary Physicians, that is, Domain Experts with deep knowledge and great clinical experience in Veterinary Medicine were consulted and assisted the researcher to develop and construct the FCM models for assessing the severity of the two poultry diseases using the algorithms in sections 3. Expert defined the main features (concepts) that play important role in the diagnosis of poultry diseases.

All the models were developed using expert-based approach as captured in our developed algorithms.

FCM model for Gumboro decision making

The developed FCM model for Gumboro decision making was developed consisting of the following seventeen (17) concepts; C1: Anorexia, C2: Depression, C3: Ruffled Feathers, C4: Dehydration, C5: Trembling, C6: Loss of Appetite, C7: Watery Diarrhea, C8: Vent Pecking, C9: Poor or Lack of Appetite, C10: Huddling under Equipment, C11: Unsteady Gait, C12: Reluctance to Rise, C13: Dehydrated, C14: Swollen Feces, C15: Prostration C16: Inflammation of Cloaca, and DS1: Severity of the Disease.

In view of this, seventeen (17) fuzzy sets were developed for assessing the severity of Gumboro for appropriate decision making.

The three Experts' opinions for assessing the severity of Gumboro in order to provide a novel decision-support tool, showing the relationships between concepts and their associated weights according to the algorithms presented earlier are presented as follows:

First Expert's Opinion: The opinion of the first expert for assessing the severity of Gumboro is shown in Figure 3 and the associated linguistic weights are shown in the adjacency matrix in Table 1:

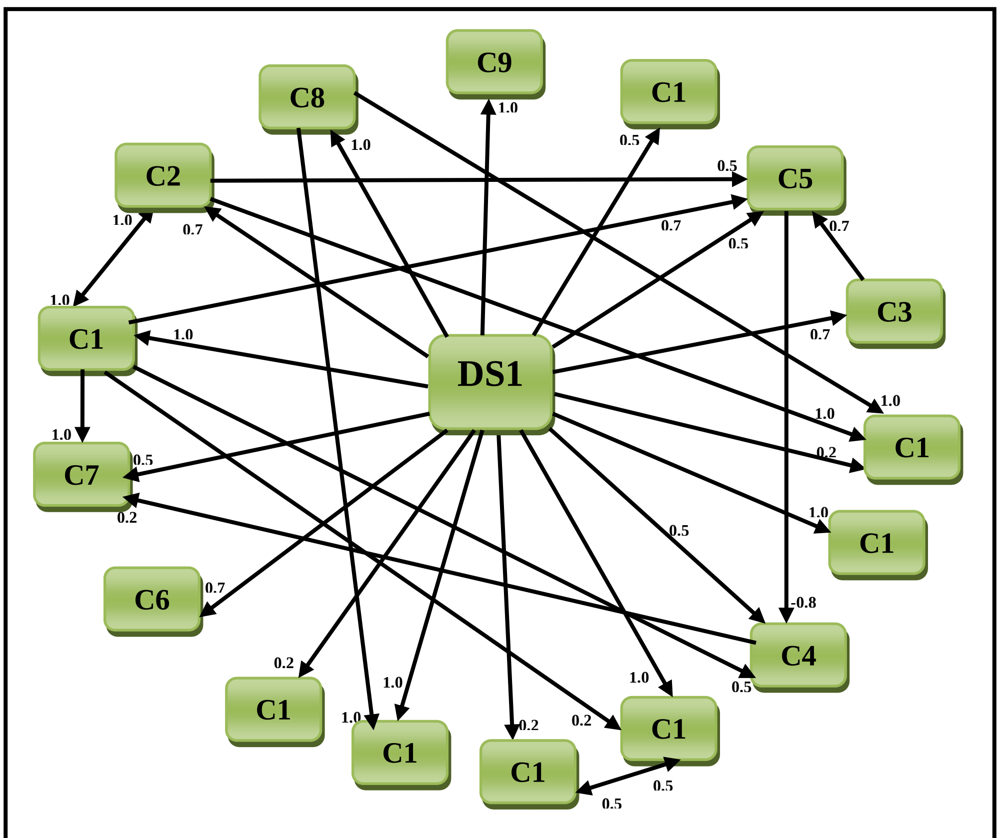

Figure 3: Expert 1-FCM Model for Assessing the Severity of Gumboro

Table 1: Expert 1 - Linguistic Weights for Assessing the Severity of Gumboro

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	DS1
C1	0	1.0	0	0.5	0.7	0	1.0	0	0	0	0	0.2	0	0	0	0	0
C2	1.0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	1.0	0
C3	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	-0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	1.0	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS1	1.0	0.7	0.7	0.5	0.5	0.7	0.5	1.0	1.0	0.2	0.5	1.0	0.2	1.0	1.0	0.2	0

Second Expert's Opinion: The opinion of the second expert for assessing the severity of Gumboro is shown in Figure 4 and the associated linguistic weights are shown in the adjacency matrix in Table 2:

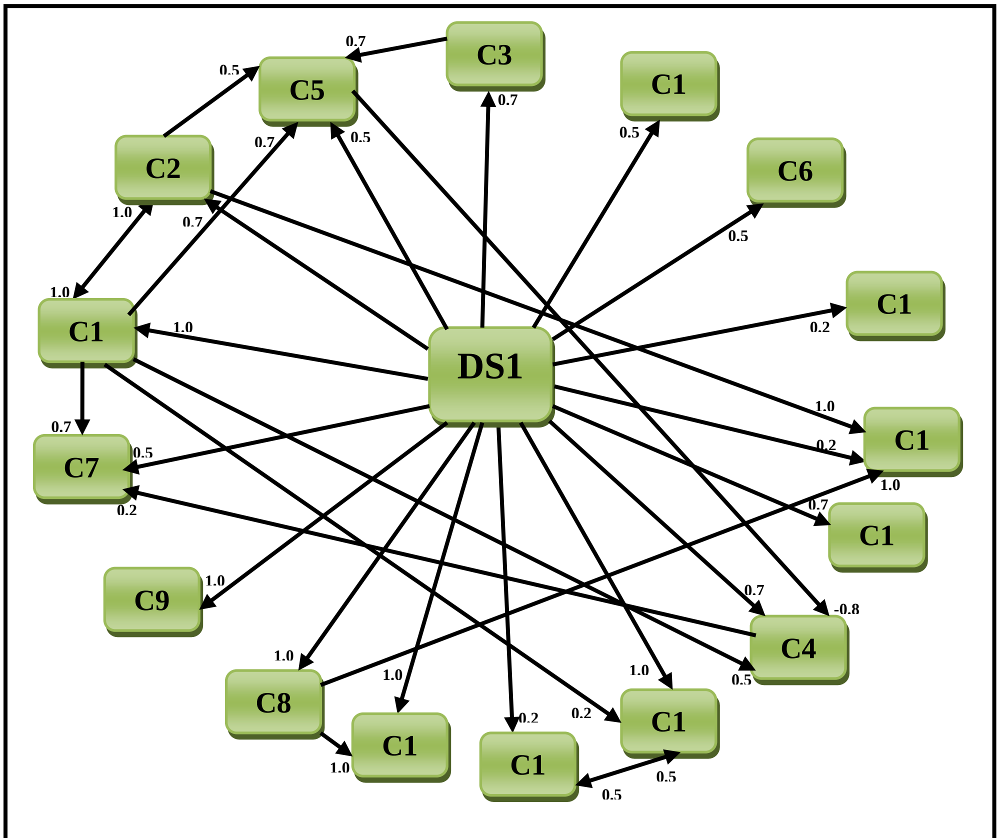

Figure 4: Expert 2 - FCM Model for Assessing the Severity of Gumboro

Table 2: Expert 2 - Linguistic Weights for Assessing the Severity of Gumboro

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	DS1
C1	0	1.0	0	0.5	0.7	0	0.7	0	0	0	0	0.2	0	0	0	0	0
C2	1.0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	1.0	0
C3	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	-0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	1.0	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS1	1.0	0.7	0.7	0.7	0.5	0.5	0.5	1.0	1.0	0.2	0.5	1.0	0.2	0.7	1.0	0.2	0

Third Expert's Opinion: The opinion of the third expert for assessing the severity of Gumboro is shown in Figure 5 and the associated linguistic weights are shown in the adjacency matrix in Table 3:

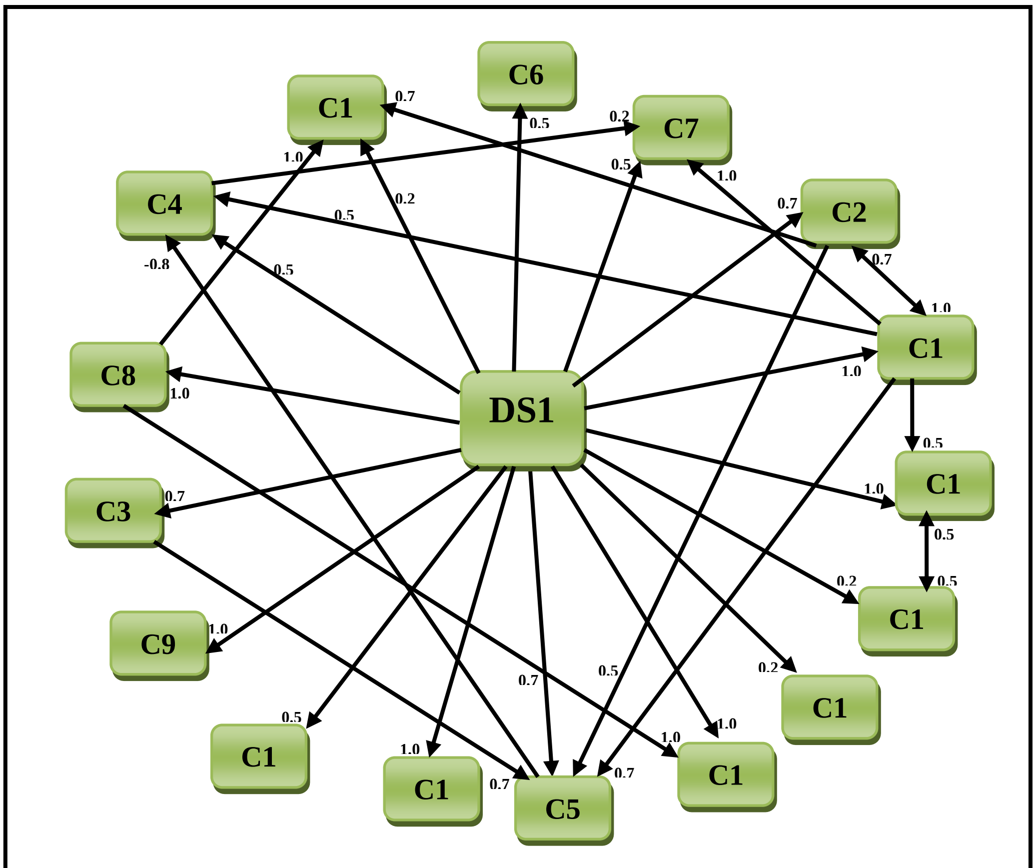

Figure 5: Expert 3 - FCM Model for Assessing the Severity of Gumboro

Table 4: Expert 3 - Linguistic Weights for Assessing the Severity of Gumboro

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	DS1
C1	0	0.7	0	0.5	0.7	0	1.0	0	0	0	0	0.5	0	0	0	0	0
C2	1.0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.7	0
C3	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	-0.8	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	1.0	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS1	1.0	0.7	0.7	0.5	0.7	0.5	0.5	1.0	1.0	0.2	0.5	1.0	0.2	1.0	1.0	0.2	0

The overall linguistic weights assigned by the various experts for assessing the severity of Gumboro are presented in Table 5:

Table 5: Overall Linguistic Weights - Overall Weight Matrix for Assessing the Severity of Gumboro

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	DS1
C1	0	2.7	0	1.5	2.1	0	2.7	0	0	0	0	0.9	0	0	0	0	0
C2	3.0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	2.7	0
C3	0	0	0	0	2.1	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	-2.4	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0	3.0	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS1	3.0	2.1	2.1	1.7	1.7	1.7	1.5	3.0	3.0	0.6	1.5	3.0	0.6	2.7	3.0	0.6	0

Using sigmoid function $f(x) = \frac{1}{(1+e^{-x})}$, the overall weight matrix for assessing the severity of Gumboro in Table 5, was normalized in the interval [-1, 1] as shown in Table 6:

Table 6: Normalized Overall Weight Matrix for Assessing the Severity of Gumboro

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	DS1
C1	0	0.9302	0	0.8176	0.8909	0	0.9302	0	0	0	0	0.9	0	0	0	0	0
C2	0.9526	0	0	0	0.8176	0	0	0	0	0	0	0	0	0	0	0.9302	0
C3	0	0	0	0	0.8909	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0.0832	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9526	0.9526	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0.8176	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0.8176	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS1	0.9526	0.8909	0.8909	0.8455	0.8455	0.8455	0.8176	0.9526	0.9526	0.6	0.8176	0.9526	0.6	0.9302	0.9526	0.6	0

Augmented FCM Model for Gumboro: Figure 6 illustrates an augmented FCM model for assessing the severity of Gumboro (derived from the above overall weight matrix in table 6:

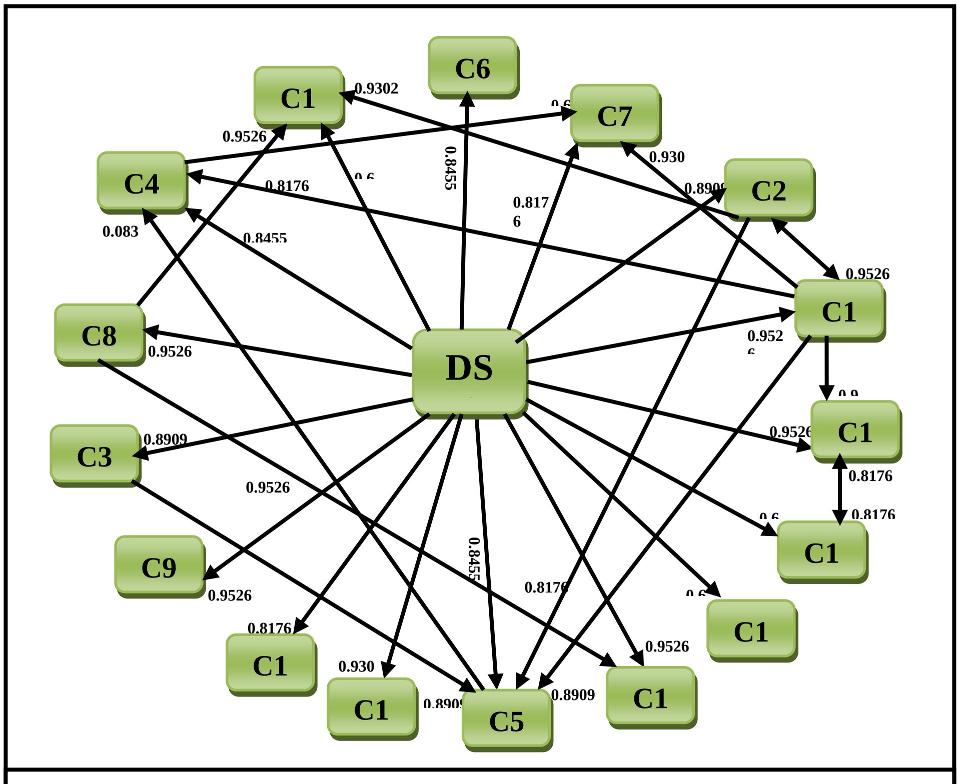

Figure 6: Augmented FCM Model for Assessing the Severity of Gumboro

FCM model for fowl typhoid fever decision making

The developed FCM model for fowl typhoid fever decision making was developed consisting of the following thirteen (13) concepts; C1: Drooping Wings, C2: Shivering, C3: Huddling near a blight source, C4: Muscular Incoordination, C5: Bloody Stool, C6: Twisted head and neck, C7: Cloudiness and Enlargement of the eyes, C8: Dejection, C9: Ruffled Feathers, C10: Inappetence C11: Yellow Diarrhea, C12: Widal test, DS2: Severity of the Disease.

In view of this, thirteen (13) fuzzy sets were developed for assessing the severity of fowl typhoid fever for appropriate decision making.

The three Experts' opinions for assessing the severity of fowl typhoid fever in order to provide a novel decision-support tool, showing the relationships between concepts and their associated weights according to the algorithms presented earlier are presented as follows:

First Expert's Opinion: The opinion of the first expert for assessing the severity of fowl typhoid fever is shown in Figure 7 and the associated linguistic weights are shown in the adjacency matrix in Table 7:

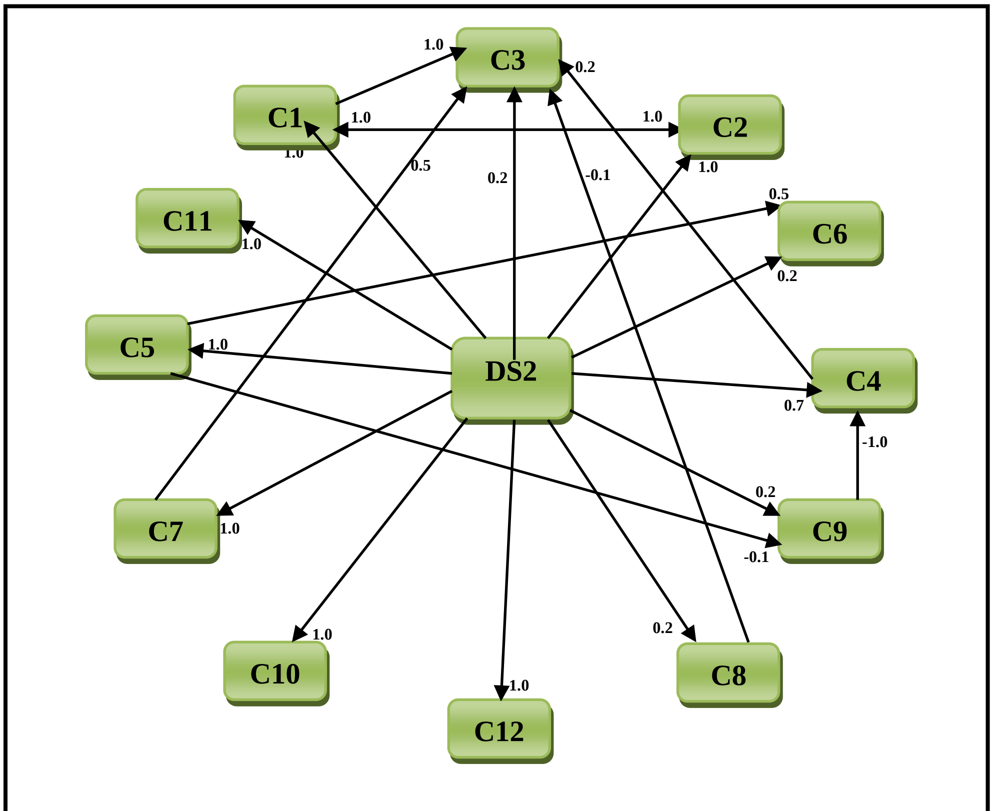

Figure 7: Expert 1 - FCM Model for Assessing the Severity of Fowl Typhoid Fever

Table 7: Expert 1 - Linguistic Weights for Assessing the Severity of Paratyphoid Fever

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	DS2
C1	0	1.0	1.0	0	0	0	0	0	0	0	0	0	0
C2	1.0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0.2	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0.5	0	0	-0.1	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0.5	0	0	0	0	0	0	0	0	0	0
C8	0	0	-0.1	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	-1.0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	.0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	1	1	0.2	0.7	1.0	0.2	1	0.2	0.2	1	1.0	1.0	0

Second Expert's Opinion: The opinion of the second expert for assessing the severity of fowl typhoid fever is shown in Figure 8 and the linguistic weights are shown in the adjacency matrix in Table 8: 0.2

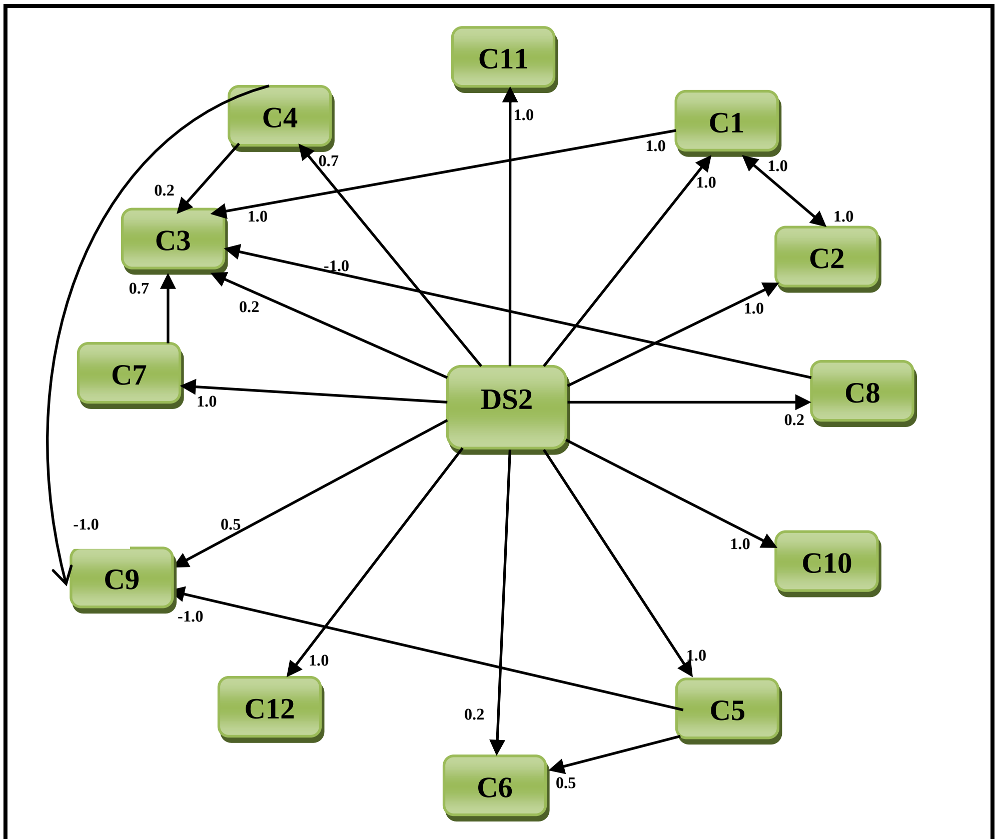

Figure 8: Expert 2 - FCM Model for Assessing the Severity of Fowl Typhoid Fever

Table 8: Expert 2 - Linguistic Weights for Assessing the Severity of Fowl Typhoid Fever

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	DS2
C1	0	1.0	1.0	0	0	0	0	0	0	0	0	0	0
C2	1.0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0.2	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0.5	0	0	0	0	0	-1.0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0.7	0	0	0	0	0	0	0	0	0	0
C8	0	0	--1.0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	-1.0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	1.0	1.0	0.2	0.7	1.0	0.2	1.0	0.2	0.5	1.0	1.0	1.0	0

Third Expert's Opinion: The opinion of the third expert for assessing the severity of fowl typhoid fever is shown in Figure 9 and the associated linguistic weights are shown in the adjacency matrix in Table 9:

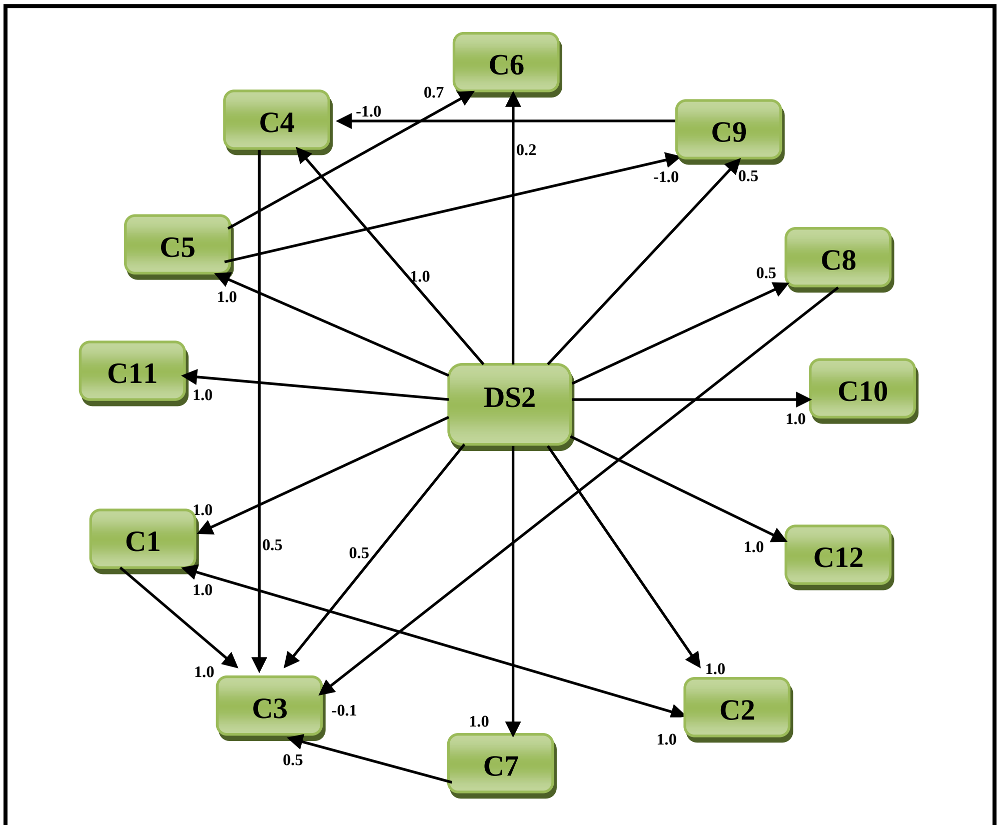

Figure 9: Expert 3 - FCM Model for Assessing the Severity of Fowl Typhoid Fever

Table 9: Expert 3 - Linguistic Weights for Assessing the Severity of Fowl Typhoid Fever

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	DS2
C1	0	1.0	1.0	0	0	0	0	0	0	0	0	0	0
C2	1.0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0.5	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0.7	0	0	-1.0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0.5	0	0	0	0	0	0	0	0	0	0
C8	0	0	-1.0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	-1.0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	1.0	1.0	0.5	1.0	1.0	0.2	1.0	0.5	0.5	1.0	1.0	1.0	0

The overall linguistic weights assigned by the various experts for assessing the severity of fowl typhoid fever are presented in Table 10:

Table 10: Overall Linguistic Weights - Overall weight matrix for Fowl Typhoid Fever

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	DS2
C1	0	3.0	3.0	0	0	0	0	0	0	0	0	0	0
C2	3.0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0.9	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	1.7	0	0	0	0	0	-3.0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	1.7	0	0	0	0	0	0	0	0	0	0
C8	0	0	-3.0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	-3.0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	3.0	3.0	0.9	2.4	3.0	0.6	3.0	0.9	1.2	3.0	3.0	3.0	0

Using sigmoid function $f(x) = \frac{1}{(1+e^{-x})}$, the overall weight matrix for assessing the severity of fowl typhoid fever in Table 10, was normalized in the interval [-1, 1] as shown in Table 11:

Table 11: Normalized Overall Weight Matrix for Assessing the Severity of Fowl Typhoid Fever

Concepts	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	DS2
C1	0	0.9526	0.9526	0	0	0	0	0	0	0	0	0	0
C2	0.9526	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0.9	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0.8455	0	0	0	0	0	0.0474	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0
C7	0	0	0.8455	0	0	0	0	0	0	0	0	0	0
C8	0	0	0.0474	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0.0474	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	0.9526	0.9526	0.9	0.9168	0.9526	0.6	0.9526	0.9	0.7685	0.9526	0.9526	0.9526	0

Augmented FCM Model for Fowl Typhoid Fever: Figure 10 below illustrates an augmented FCM model for assessing the severity of fowl typhoid fever (derived from the above overall weight matrix in table 11:

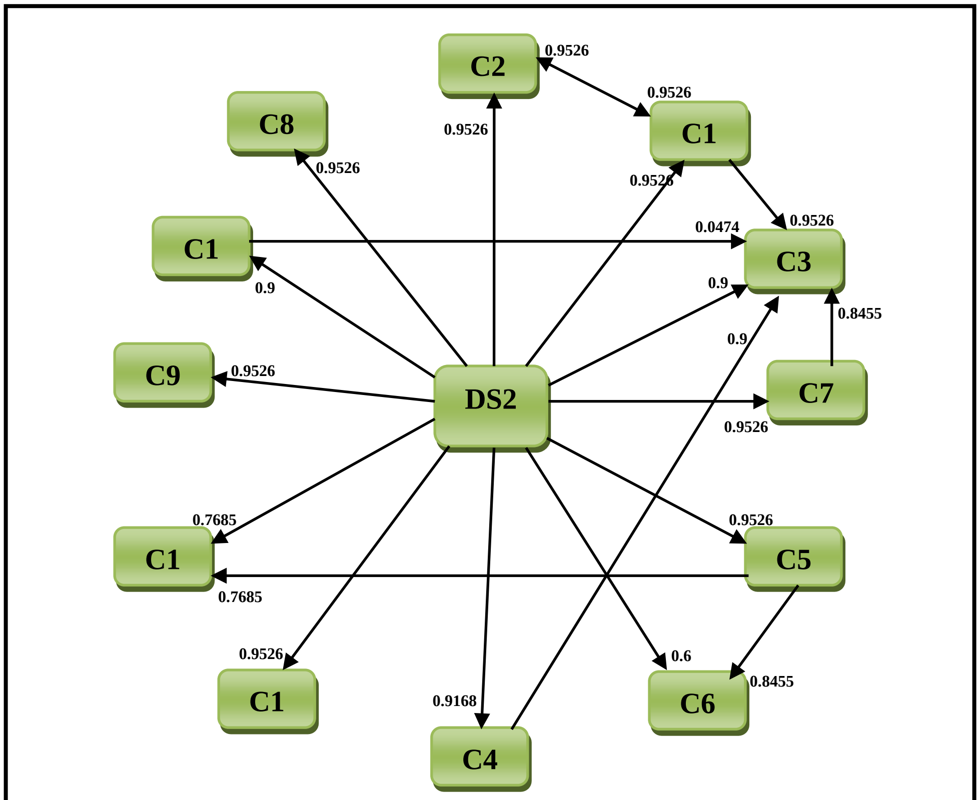

Figure 10: Augmented FCM Model for Assessing the Severity of Fowl Typhoid Fever

CONCLUSION

Fuzzy set theory also known as fuzzy logic is an extension of classical set theory. Fuzzy set theory functions can be applied in agriculture, helping farmers make the right decisions for diagnosing poultry diseases. Hence, it contributes better to estimating the quality of poultry production which by extension brings economic development.

In this article, severity of poultry diseases is assessed via the augmented FCM. Three Experts' opinions for assessing the severity of fowl typhoid fever and Gumboro was considered in order to provide a novel decision-support tool, showing the relationships between concepts and their associated weights according to the algorithms. Results obtained were fast and accurate.

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