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## **A K-means and fuzzy logic-based system for clinical diagnosis (staging) of cervical cancer**

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**Abstract:** In cases of the burden arising from cancer world, cervical cancer is the most common type of gynaecological cancer, accounting 8% (527,624 cases in 2012) of all female malignancies, second only to breast and colorectal cancer. Women with cervical cancer constitute patient populations that are in need of ongoing, person-centred supportive care. The unavailability of technologies that can determine the stage of cervical cancer constitutes a problem in the actual diagnosis. Previously physician predict the cancer stage on the basis of their experience in the field, however this is prone to error because man's judgement are sometimes clouded by emotions. This research seeks to address this problem with the design of a k-means and fuzzy logic based system for clinical diagnosis (staging) of cervical cancer. The K-means algorithm was used for the grouping of data and fuzzy logic for the rule based prognosis of cervical cancer.

**Keywords:** cervical cancer; fuzzy logic; K-means; diagnosis; staging; algorithm; rule-based; prognosis.

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## 1 Introduction

The leading causes of death among women are stroke, diabetes, heart disease, cancer and kidney disease. Aside heart disease which had about 22.4% of all causes of death in women, cancer followed up with a 21.5%, thereby ranking second among the leading cause of death in the USA (PRC, 2015).

Cervical cancer is a malignant neoplasm arising from cells originating in the cervix uteri (CDL, 2016; Dibya, 2014). It tends to have the ability of not being visible until it reaches an advance stage (WHO, 2006; skylinefamilypractice, 2016; Wikipedia, 2016). Pap smear screening is a screening that identifies pre-cancerous changes which further leads to cervical cancer (NCI, 2016b; ACS, 2016). Through pap smear screening, treatment can be administered to a patient having cervical cancer. Most issues of cervical cancer are repeatedly caused by *human papilloma virus* (HPV) infection, particularly the HPV type 16 and 18 (WHO, 2016; NCI, 2016a; NHS, 2015; Eilean, 2003).

In the UK for instance, there are around 3,200 new cases of cervical cancer, that is around nine cases diagnosed every day. The pandemic is known for its alarming rate of taking a woman's lives around the world at least every two minutes. This devastating condition surrounding women has modelled a need to tackle one of the leading causes of death among women (WHO, 2016).

In Africa, high incidence of cervical cancer is reported generally at rates exceeding 50 per 100,000 populations and age-standardised mortality sometimes exceeding 40 per 100,000 populations. An estimated 53,000 women die of the disease every year (WHO, 2014; Abiodun et al., 2014). Eastern, Western and Southern African countries have the highest incidence rate of cervical cancer. Malawi has the highest rate of 75.9 per 100,000 in the country, followed by Mozambique with rates of 65 per 100,000 populations (ADI & ACM, 2014; Maseko et al., 2015). In sub-Saharan Africa countries like Gabon, Gambia, Angola etc, cervical cancer accounts for 22.2% of all cancer occurrence and the most common cause of death (Atara, 2012). In Nigeria, cervical cancer is a major cause of mortality among females which are in their most productive age. It ranks the second most frequent cancer in women in Nigeria between 15 and 45 years of age (Abah, 2012; Isah et al., 2014). Approximately, 1 of every 4,000 women develops cervical cancer (Ndikom and Ofi, 2012).

Hospitals have been reputable for providing counsel, diagnosis and treatment to patients with diseases of this nature thereby reducing fatalism among humans. As it is often said that 'health is wealth', however, over the years, research revealed that health institutions have been quite unsuccessful at managing and attending to patients needing medical help on a large-scale (Claire, 2001). This is especially true, owing to the rising figures of casualties and limited existing health infrastructures which is not sufficiently developed to support screening programs. Sometimes, having completed screening programs employed in some medical industry, there are still cases of inconsistency, that is, cases whereby more accurate recognition of tumours is needed to establish the status [International Federation of Gynecology and Obstetrics (FIGO) stage] of one's predicament. Thus, it is evident that the presence of hospitals together with qualified persons is not enough to combat this epidemic. Due to the uprising number of individuals seeking help one way or the other regarding their health, it is important that advancement in technology as seen in numerous areas pertaining to the health industry be taken into consideration in order to make living life in good health a dream come through for all (Timothy, 2010). Automation therefore must to be infused into health industry through the use of computer technology and mechanism (Alasdair et al., 2008).

Interestingly, cervical cancer unlike other cancers is 100% preventable if detected and treated early. They are being prevented from progressing to invasive cancers by using repeated pap smear screening for treatment (Ertem, 2009).

This research seeks to address the above problem with the development of a K-means and fuzzy logic based system for clinical diagnosis (staging) of cervical cancer. This system is knowledge based system designed to receive queries made up of user inputs and in turn display an output based on the inputs that satisfy the conditions for the particular stage of cervical cancer. These queries which contain test results of the disease is processed by the expert system using its knowledge base maintained by experts in the medical field and provide efficient diagnosis. Cervical cancer has been predicted to have four stages including two sub-stages A and B for each of the stages, that is, 1A, 1B, 2A, 2B, 3A, 3C, 4A and 4B apart from the stage 0 which doesn't necessarily develop into cervical cancer.

The K-means algorithm was implemented using the Waikato Environment for Knowledge Analysis (WEKA) tool while the Fuzzy prediction was implemented using the Matrix Laboratory (MATLAB) tool.

## **2 Literature review**

### *2.1 Fuzzy rules and fuzzy inference*

The fuzzy rule base is characterised in the form of if-then rules in which pre-conditions and consequents involve linguistic variables. The collection of these rules forms the rule base for the fuzzy logic system. Due to their concise form, fuzzy if-then rules are often employed to capture the imprecise manner of translation that plays a fundamental role in human's ability to make decisions in an environment of doubt and imprecision. A single fuzzy if-then rule takes the form:

*If x is A  
THEN y is B.*

where  $A$  and  $B$  are linguistic values determined by fuzzy sets on the universes of discourse (range)  $x$  and  $y$ , respectively. The if-part of the rule ' $x$  is  $A$ ' is referred to as antecedent (pre-condition), while the then part of the rule ' $y$  is  $B$ ' is referred to as conclusion (Aboul-Ella and Ajith, 2008).

Fuzzy inference is the mapping of input value to an output value employing the use of fuzzy set theory. There are different fuzzy inference technique, however the most commonly used one is the Mamdani-style fuzzy inference technique also known as Mamdani method. This method is performed in four steps which are:

- 1 fuzzification of the input variables
- 2 rule evaluation
- 3 aggregation of the rule outputs
- 4 defuzzification

Fuzzification is the mapping of a crisp input of value to an appropriate fuzzy set. It is the first step that takes crisp inputs and determines the degree to which the taken inputs belong to each of the appropriate fuzzy sets (Ying and Dali, 2007; Reeda et al., 2013). Rule evaluation explains the mapping of a fuzzified input to a fuzzy operator. It is the second step to take the fuzzified inputs and apply them to the antecedents of the fuzzy rules. The number of antecedents in a fuzzy rule determines the fuzzy operator to be used to obtain a single number that can represent the result of the antecedent (precondition) evaluation (Reeda et al., 2013).

Aggregation of the rule outputs is the process of unifying all rules. It actually the combination of all rules consequents preciously clipped into a single fuzzy set (Reeda et al., 2013). De-fuzzification is the process of evaluating rules. It is the last step in the fuzzy inference process that concerns itself more with the output of a system which must

be in crisp form. There are several de-fuzzification methods albeit the most popular among them is the centre of gravity (COG) (Ying and Dali, 2007).

## 2.2 Overview of data clustering

In early 80s, Gio Wiederhold, Robert Blum and Gregory Piatetsky-Shapiro, among others, began to associate data mining and knowledge discovery in databases (KDD) terms using particularly four types of techniques which are: Association rule learning, classification, regression and clustering (Fayyad et al., 1996). Clustering simply put is the unsupervised classification of patterns (data items) into groups (clusters) (Jain et al., 1999). On the other hand, Data clustering is a method concerned with the task of grouping a set of related objects (probably from a patient's health history, physical examination or laboratory results) in the same group (cluster) into a newer close group (diagnosis or prescription) with objects closely or similarly associated.

However, when clustering happens in a dataset, it gives birth a high intra-cluster similarity-description of the similarity between clusters and Low inter-cluster similarity-description of the dissimilarity between the clusters (Lior and Oded, 2011).

### 2.2.1 Classification of clustering

Clustering technique application depends on the problem statement. There is no particular or preferred model over another for solving a problem except experimentally proven with mathematical reason. Each clustering type possesses its own flaws. To achieve clustering, a similarity or dissimilarity measure (matching) must be determined, it is this measure that help reflect the degree of association of the objects (either close or separate) which must correspond to the characteristics that distinguishes the clusters present in the data. There are different types of measures (distance measure) which include: Euclidean distant measure, Manhattan distance measure, Cosine distance measure etc. In tackling our problem, *k means algorithm* – exclusive clustering and the Euclidean distant measure was chosen for the clustering of our datasets.

### 2.2.2 K-means algorithm

This is one of the most common methods of clustering. It starts with a set of K reference points and data points belonging to K clusters based on distance criterion (Markela et al., 2015).

In this algorithm, samples are subdivided into six clusters (Markela et al., 2015);

$$\text{objective function} \leftarrow J = \sum_{j=1}^k \sum_{i=1}^n \|x_i^{(j)} - c_j\|^2$$

The diagram illustrates the K-means objective function formula with the following annotations:

- number of clusters**: Points to the variable  $k$  in the outer summation.
- number of cases**: Points to the variable  $n$  in the inner summation.
- case  $i$** : Points to the data point  $x_i^{(j)}$ .
- centroid for cluster  $j$** : Points to the centroid  $c_j$ .
- Distance function**: Points to the norm symbol  $\| \cdot \|$  in the expression  $\|x_i^{(j)} - c_j\|^2$ .
- objective function**: Points to the variable  $J$ .

### *2.3 Diagnosis and stages of cervical cancer*

For the diagnosis of cervical cancer, it is of note necessary for an individual with this illness to go to the hospital for the following check-up (Maclean et al., 2016; NCI, 2014c):

- 1 physical examination, pelvic examination and pap test.
- 2 a colposcopy and cervical biopsy, endocervical biopsy or curettage, cone biopsy or loop electrosurgical excision procedure (LEEP)
- 3 a test to confirm the stage (extent) of the cervical cancer, this includes chest x-ray, CT scan, ultrasound, MRI, PET scan and a biopsy using first-needle aspiration.

Test 1 is normally performed by a doctor manually with the use of his bare hands while tests 2 and 3 are tests taken to know the relative closure of the cancer with the cervical region and the respective damage stage (extent) of the cervical cancer in the cervix. Cervical cancer makes use of the FIGO staging system. The FIGO staging system makes use of the findings gotten from various clinical examinations rather than surgical findings. These clinical examinations include physical examination, palpation, colposcopy, hysteroscopy, protoscopy, cystoscopy, sigmoidoscopy, endocervical, curettage, cervical conisation, intravenous urography, x-ray examination of the lungs and skeleton. After this series of tests are performed, the stages of cervical cancer are classified into four classes having A and B respectively i.e. 1A, 1B, 2A, 2B, 3A, 3B, 4A and 4B.

There are a variety of stages of cervical cancer that identify the extent and site of infection. The first stage is stage 0 which is also known as cervical carcinoma in situ, it is located at the top layer of cells along the cervix line carcinoma in situ. It is not considered as cancer but in some cases it may develop into cancer if left untreated (Jyotsna, 2010; Cancer Research UK, 2014).

Stage 1 cervical cancer is only found in the cervix. Stage 1 is further divided into two groups A and B. In stage 1A only a small microscopic cancer is in the cervical tissue and is about 5–7 millimetres, the stage 1B may be just slightly wider than seven millimetres and may be as large as four centimetres that can be visible even without a microscope (Jyotsna, 2010).

Stage 2 cervical cancer spreads from the cervix into the upper part of the vagina. Stage 2A means it has spread to about two thirds of the vagina but having not touched the other surrounding tissues of the uterus unlike stage 2B where it may slightly spread into other tissues around the uterus as along with the two thirds of the vagina (Jyotsna, 2010).

Stage 3 cervical cancer spread into the lower part of the vagina and spread to the pelvic wall and the surrounding lymph nodes. In 3A cervical cancer spreads to the lower third of the vagina but does not affect the pelvic wall. Stage 3B cervical cancer spreads to pelvic wall, the tumour is large enough that it could block the ureters causing the risk of the kidney to enlarge or even seize to function with the risk of also having lymph nodes infected (Jyotsna, 2010).

The most crucial stage is stage 4 which has cervical cancer spread to the bladder, rectum and even other parts of the body. In the stage 4B the cervical cancer may even spread to the liver, intestinal tract or lungs causing it to be a very deadly level (Jyotsna, 2010).

## 2.4 *Review of related work*

In the diagnostic area of understanding the risks and negative impacts of cervical cancer disease, researchers are fully aware that this disease is preventable and curable at a low cost and low risk if accurate diagnosis is performed in due time. Various expert systems have been designed to imitate the decision making capabilities of human experts in this area.

Sharma and his research colleagues classified a clinical dataset of cervical cancer to identify the stage of cancer which helps in proper treatment of patient suffering from cancer. In their paper, Edge detection classification system was used to separate the cell nuclei from cytoplasm and background and then extract various features of cervical pap images like area, perimeter, elongation and then these features are normalised using min-max method. After normalisation KNN method was used to classify cancer according to its abnormality. Their research work in the detection of cervical cancer using pap smear images, showed that analysis of Pap smear of cervical region is an efficient technique to study any abnormality in cervical cell.

Mohammed et al. (2014) developed a multiple adaptive neuro-fuzzy inference system (MANFIS) with automatic features extraction (AFE) algorithm for cervical cancer recognition. The developed system consists of two stages. In the first stage, the AFE algorithm is performed. In the second stage, a neuro-fuzzy model called MANFIS is proposed for recognition process. The MANFIS contains a set of ANFIS models which are arranged in parallel combination to produce a model with multi-input-multi output structure. The system is capable of classifying cervical cell image into three groups, namely, normal, low-grade squamous intraepithelial lesion (LSIL) and high-grade squamous intraepithelial lesion (HSIL).

Karem et al. (2013) developed an expert system which supports the diagnosis of cervical cancer in typical glandular cells, based on fuzzy logics and image interpretation. Hernandez and his colleagues described the progress of a trained process ready to furnish a prognosis to cervical neoplasia (CN) precursor injuries by means of the integration of fuzzy logics and image interpretation strategies. Their trained procedure contained three phases 'risk diagnosis, cytology graphics and selection of melanoma precursor injuries'. During the validation stage of their process, 21 already identified instances were confirmed with a positive correlation wherein 100% effectiveness was received. The essential contribution of their work depended on the reduction of false positives and false negatives by using an extra correct analysis for CN. They were also able to describe an expert system that was able to provide a diagnosis to CN precursor injuries through the integration of fuzzy logics and image interpretation techniques.

Karem et al. (2013) presented an expert system based on image processing and fuzzy logic.

Rahmadwati et al. (2012) investigated cervical cancer diagnosis based on the morphological characteristics of cervical cells. The developed algorithms cover several steps: pre-processing, image segmentation, nuclei and cytoplasm detection, feature calculation and classification. The K-means clustering algorithm based on colour segmentation was used to segment cervical biopsy images into five regions: background, nuclei, red blood cell, stroma and cytoplasm. The morphological characteristics of cervical cells were used for feature extraction of cervical histopathology images. The cervical histopathology images were classified using four well known discriminatory features:

- 1 the ratio of nuclei to cytoplasm
- 2 the diameter of nuclei
- 3 the shape factor
- 4 the compactness of nuclei.

Finally, the images are analysed and classified into appropriate classes. This method is utilised to classify the cervical biopsy images into normal, pre-cancer (cervical intraepithelial neoplasia (CIN1, CIN2, CIN3)) and malignant.

Mochoro (2010) developed an expert system that could rid-off subjectivity that may come up due to colposcopy specialist different opinions. The gynaecologists can use the information produced by the system as an alternative for decision making in diagnosing the type of CN precursor injury based on fuzzy logics and colposcopic image processing.

Tan (2011) proposed a guide to facilitate the implementation of the image-guided brachytherapy (IGBT) which is one the high end techniques for cervix cancer treatment. This research was published by Royal College of Radiologist (RCR) I 2009.

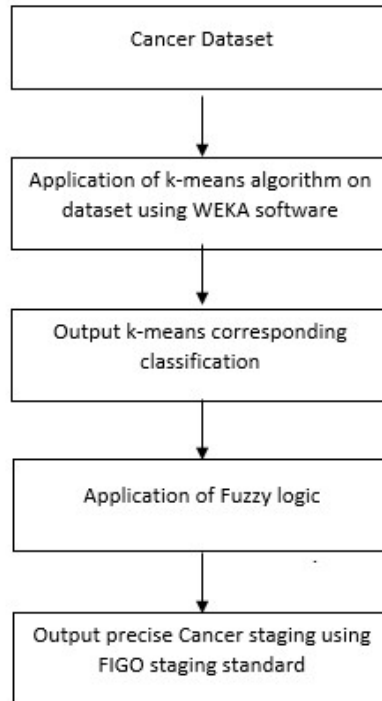
Petric et al. (2008) conducted a test on 13 patients in which high risk CTV (HR-CTV) was identified by two observers in T and PT MR image plane respecting the GYN GEC-ESTRO recommendations for 3D-image based cervix cancer bradytherapy. HR-CTV sizes were compared and conformity index (CI) was accessed. Inter observer variations in contour latent along eight radial directions were compared between declination planes.

Nor et al. (2008) developed an automated pre-cancerous diagnostic system which described an automatic feature extraction and an intelligent diagnostic using a feature extraction algorithm called region growing based features extraction (RGBFE) and a new artificial neural network architecture called hierarchical hybrid multi-layered perception network.

Oguntoyinbo et al. (2005) described how to design and implement a prototype of a cancer diagnostic system which could diagnose breast, ovarian and cervical cancer using Bayesian formula.

Mitra et al. (2002) described a way of designing a hybrid decision support system in soft computing paradigm for detecting the different stages of cervical cancer. Hybridisation includes the evolution of knowledge based subnet work modules with genetic algorithms using rough set theory and the Interactive Dichotomizer 3 (ID3) algorithm. The evolution used a restricted mutation operator which utilises the knowledge of the modular structure, already generated, for faster convergence. The aforesaid integration enhances the performance in terms of classification score, network size and training time, as compared to the conventional multilayer perceptron. Their methodology also helps in imposing a structure on the weights, which results in a network more suitable for extraction of logical rules and human interpretation of the inferencing procedure

Samuel et al. (1996) proposed an expert system for the detection of cervical cancer cells using knowledge-based image analyser to reduce deaths and morbidity from cervical cancer through detection of potentially cancerous cells, provision of prompt advice and opportunities for follow up and treatments.

**Figure 1** System modules relationship

### 3 Methodology

#### 3.1 The proposed system

A predictive model which determines the relationship between the inputted entry and the FIGO staging is developed. The cancer dataset that represent the result of patients having cancer were extracted from International Gynecological Cancer System (IGCS). K-means clustering algorithm is performed on this datasets which contains 13 elements using the WEKA software which is then used as an optimisation tool for searching meaningful relationship between the original classified groups of the cancer patients, then reclassifies the dataset based on some rules. Fuzzy logic is then used to deduce rules that can serve rules that can serve as a model for predicting cancer stages in accordance with the standard FIGO staging system.

#### 3.2 Dataset

The dataset employed in this study was a secondary data acquired from IGCS an online source provided by Nairayan Kailash. A total sample size of 237 records was used.

**Figure 2** Dataset (see online version for colours)

The screenshot shows an Excel spreadsheet titled 'CervicalCancer\_Narayan\_IGCS(I) [Compatibility Mode] - Excel'. The spreadsheet contains a dataset of cervical cancer patients. The columns are labeled as follows: A (Patient ID), B (Histology), C (FIGO), D (node pet), E (Clinical diameter cm), F (MRI-VOL CC), G (Uterine body), H (Status), I (Rel Primary), J (Rel Pelvic), K (Rel Abdo), L (Rel Supraclav), and M (Rel Distant). The data is organized into rows, with some cells highlighted in red. The status column (H) shows 'INVOLVED' and 'RECURRENT'. The relapse indicators (I-M) show 'Yes' and 'No'.

Source: IGCS

**Table 1** Baseline characteristics

| Variable          | Level         | Number of patients |
|-------------------|---------------|--------------------|
| Histology         | Clear cell    | 5                  |
|                   | SCC           | 204                |
|                   | Endometrioid  | 26                 |
|                   | Serous        | 2                  |
| FIGO              | I             | 70                 |
|                   | II            | 114                |
|                   | III           | 52                 |
|                   | IV            | 1                  |
| Node pet          | Yes           | 107                |
|                   | No            | 130                |
| Clinical diameter | ≤ 4.0         | 106                |
|                   | ≥ 4.0         | 108                |
| MRI-VOL CC        | ≤ 314         | 236                |
|                   | ≥ 314         | 1                  |
| Uterine body      | Involved      | 169                |
|                   | Non-involved  | 68                 |
| Status            | No occurrence | 155                |
|                   | Recurrence    | 82                 |
| Rel primary       | Yes           | 237                |
| Rel pelvic        | Yes           | 237                |
| Rel abdo          | Yes           | 237                |
| Rel supraclav     | Yes           | 237                |
| Rel distant       | Yes           | 237                |

The database employed for this study contained 237 datasets (patient's record), which were successfully grouped under thirteen (13) fields (elements) which consist of: histology, FIGO, node PET, clinical diameter (cm), magnetic resonance imaging (MRI) vol cc, uterine body, status, rel primary, rel pelvic, rel abdo, rel supraclav, rel. distant.

### 3.2.1 *Data conversion*

The secondary data employed in this system was initially collected in excel spreadsheet format (.xls) but for compatibility sake with the WEKA software, it was further converted to another format (.csv) which WEKA understands and accepts.

### 3.2.2 *Data analysis and clustering*

The secondary data collected from IGCS was analysed and clustered by the WEKA software using K-means clustering algorithm to generate the relationship between each attribute of data in the datasets employed.

## 3.3 *K-means algorithm*

K-means algorithm is one of the simplest unsupervised learning algorithm that solves clustering problem that are very well known. It makes use of an easy and simple procedure to classify a given dataset. Its main aim is to cluster the datasets according to the distance between them. Each clustered group is based on the minimal distance between them. The generalised pseudo-code of traditional K-means is stated as follows:

- Step1    Input the dataset to cluster alongside the number of clusters to group data into (as input values).
- Step2    Initialise the first k clusters.
  - take first instances of k or
  - take random sampling of k elements
- Step 3    Calculate the arithmetic mean of each cluster formed in the dataset.
- Step 4    K-means assigns each record in the dataset to only one of the initial clusters.
  - each record is assigned to the nearest cluster using a measure(i.e. the Euclidean distance)
- Step 5    K-means assigns each record in the datasets in the datasets to the most similar cluster and re-calculates the arithmetic mean of all the clusters in the dataset.

## 3.4 *Fuzzy Logic*

Fuzzy logic is an extension of Boolean logic that replaces binary truth values with degrees of truth. It was first described by Zadeh in 1965, and its application in 1969 for early diagnosis domain for fuzzy logic.

Latha et al. (2005) reviewed that fuzzy logic allow membership values between 0 and 1, arguably it can provide a more realistic representation of data that was inherently noisy and imprecise. The notion of fuzzy centroids into the fuzzy clustering algorithm. This

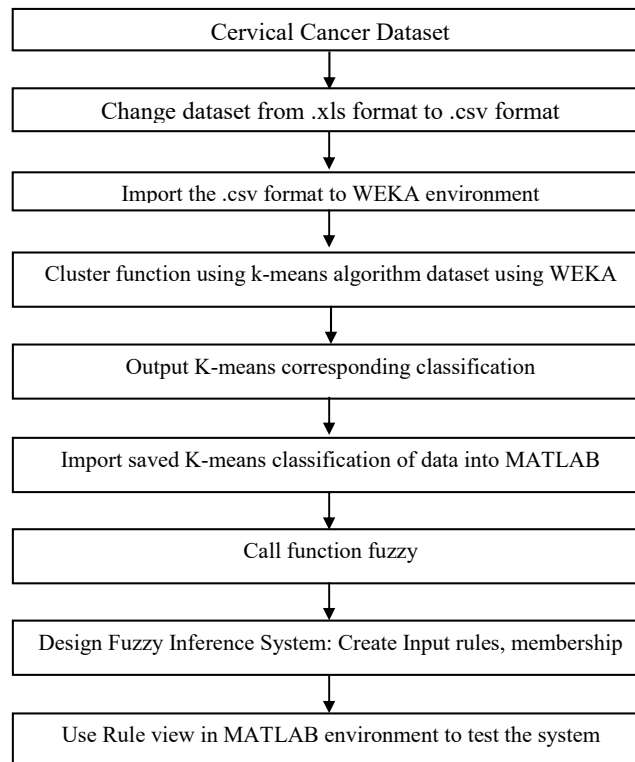
approach makes it possible to exploit the power of fuzzy sets when representing the cluster centroid.

Fuzzy logic was infused into the system using MATLAB after data clustering.

### 3.5 System flowchart

The system flowchart is illustrated in Figure 3.

**Figure 3** System flowchart



## 4 Results and discussion

### 4.1 K-means clustering

The first implementation plan is to employ the use of WEKA software to perform clusterisation by the k-means function which made use of the euclidean distance to partition data that were very similar in manner.

Figure 4 shows the structure wherein simple K-means is being performed using the WEKA application. It shows the relation which is the cervical cancer datasets which has a total number of 237 presented instances or cases containing 13 attributes which are: SN, histology, FIGO, nodePET+, Clin. Diameter cm, MRI vol., uterine body, status, rel.

primary, rel. pelvic, rel. abdo, rel. supraclav, rel. distant. And also the test mode which talks about the approach or manner of evaluating the trained data.

**Figure 4** Scheme of K-means (see online version for colours)

```

Scheme:      weka.clusterers.SimpleKMeans -init 0 -max-ca
Relation:    CervicalCancer_Narayan_IGCS(1)
Instances:   237
Attributes:  13
              SN
              Histology
              FIGO
              nodePET +
              Clin.diameter cm
              MRIVol cc
              Uterine Body
              Status
              Rel Primary
              Rel Pelvic
              Rel Abdo
              Rel SupraClav
              Rel Distant
Test mode:   evaluate on training data

```

Figure 5 shows how clusters are initially assigned. The result above is an euclidean distance evaluation of the number of clusters and the value of seed which is used in generating a random number which is in turn used for making the initial assignment of instances to clusters.

**Figure 5** K-means clustering

```

kMeans
=====

Number of iterations: 10
Within cluster sum of squared errors: 8.627380835694527

Initial starting points (random):

Cluster 0: 0.5,0,2,2.36
Cluster 1: 1,1,3,11.78
Cluster 2: 1,1,5,85.09
Cluster 3: 1,0,5,47.12
Cluster 4: 1,0,5,38.2
Cluster 5: 1,0,5,117.29
Cluster 6: 1,0,3,3.52

Missing values globally replaced with mean/mode

```

Figure 6 shows the centroid of each cluster as well as statistics on the number and percentage of instances assigned to different clusters. The cluster centroids are the mean

vectors for each cluster (so, each dimension value in the centroid represents the mean value for that dimension in the cluster). Thus centroids was used to characterise the clusters.

**Figure 6** Clustered data

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |               |             |               |               |               |               |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------|---------------|---------------|---------------|---------------|-----|
| <pre> ===== Number of iterations: 5 Within cluster sum of squared errors: 208.88467821666  Initial starting points (random):  Cluster 0: 74,Endometrioid,94,YES,4,117.61,INVOLVED,RECURRENT,Yes,Yes,Yes,Yes Cluster 1: 41,SCC,26,NO,2,2.36,'Not Involved','No recurrence',Yes,Yes,Yes,Yes Cluster 2: 177,SCC,26,YES,4,30.14,INVOLVED,'No recurrence',Yes,Yes,Yes,Yes Cluster 3: 180,SCC,26,NO,4,5.18,IS,'Not Involved','No recurrence',Yes,Yes,Yes,Yes Cluster 4: 176,SCC,26,YES,5,87.66,'Not Involved','No recurrence',Yes,Yes,Yes,Yes  Missing values globally replaced with mean/mode  Final cluster centroids:  Attribute      Full Data      Cluster#               (207.0)      0          1          2          3          4               (68.0)      (41.0)      (64.0)      (50.0)      (12.0) ===== SI              119          109.2941      90.5954      143.6212      134.14      106.6667               +/-48.8602      +/-71.8429      +/-49.0261      +/-42.8869      +/-41.3972      +/-71.2426  Histology      SCC          SCC          SCC          SCC          SCC          SCC Endometrioid   26.0 ( 10%)  11.0 ( 14%)  2.0 (  4%)  8.0 ( 12%)  5.0 ( 10%)  0.0 (  0%) SCC            204.0 ( 88%) 84.0 ( 79%) 37.0 ( 80%) 58.0 ( 87%) 43.0 ( 86%) 12.0 (100%) Sex          2.0 (  0%)  0.0 (  0%)  2.0 (  4%)  0.0 (  0%)  0.0 (  0%)  0.0 (  0%) Clear cell     0.0 (  0%)  0.0 (  0%)  0.0 (  0%)  0.0 (  0%)  0.0 (  0%)  0.0 (  0%) </pre> |               |             |               |               |               |               |     |
| Rel Pelvic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Rel Abdo                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Rel SupraClav                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Rel Distant                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Time taken to build model (full training data) : 0.08 seconds                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |               |             |               |               |               |               |     |
| == Model and evaluation on training set ==                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |               |             |               |               |               |               |     |
| Clustered Instances                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |               |             |               |               |               |               |     |
| 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 68 ( 29%)     |             |               |               |               |               |     |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 41 ( 17%)     |             |               |               |               |               |     |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 66 ( 28%)     |             |               |               |               |               |     |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 50 ( 21%)     |             |               |               |               |               |     |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 12 (  5%)     |             |               |               |               |               |     |
| PISO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |               | 2b          | 1b            | 2b            | 2b            | 2a            | 2b  |
| 2a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 34.0 ( 14%)   | 5.0 (  7%)  | 0.0 (  0%)    | 4.0 (  6%)    | 23.0 ( 46%)   | 2.0 (  4%)    |     |
| 1b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 49.0 ( 20%)   | 31.0 ( 45%) | 8.0 ( 19%)    | 6.0 (  9%)    | 21.0 ( 42%)   | 3.0 (  6%)    |     |
| 2b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 80.0 ( 33%)   | 8.0 ( 11%)  | 29.0 ( 68%)   | 36.0 ( 72%)   | 0.0 (  0%)    | 4.0 (  8%)    |     |
| 3a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 9.0 (  3%)    | 4.0 (  5%)  | 1.0 (  2%)    | 2.0 (  3%)    | 1.0 (  2%)    | 1.0 (  2%)    |     |
| 3b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42.0 ( 17%)   | 20.0 ( 29%) | 4.0 (  9%)    | 14.0 ( 28%)   | 4.0 (  8%)    | 0.0 (  0%)    |     |
| 3B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1.0 (  0%)    | 0.0 (  0%)  | 0.0 (  0%)    | 1.0 (  1%)    | 0.0 (  0%)    | 0.0 (  0%)    |     |
| 4a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1.0 (  0%)    | 0.0 (  0%)  | 0.0 (  0%)    | 1.0 (  1%)    | 0.0 (  0%)    | 0.0 (  0%)    |     |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1.0 (  0%)    | 0.0 (  0%)  | 0.0 (  0%)    | 0.0 (  0%)    | 1.0 (  2%)    | 0.0 (  0%)    |     |
| nodePET +                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |               | Ho          | YES           | Ho            | YES           | Ho            | YES |
| YES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 107.0 ( 45%)  | 51.0 ( 75%) | 0.0 (  0%)    | 43.0 ( 86%)   | 1.0 (  2%)    | 12.0 (100%)   |     |
| Ho                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 130.0 ( 54%)  | 17.0 ( 25%) | 41.0 (100%)   | 23.0 ( 46%)   | 49.0 ( 98%)   | 0.0 (  0%)    |     |
| Clin.diameter cm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4.4203        | 5.2721      | 4.3171        | 4.947         | 3.54          | 4.6667        |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | +/-1.3981     | +/-1.3055   | +/-1.359      | +/-1.1406     | +/-1.1555     | +/-1.4975     |     |
| MRIVol cc                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 58.9106       | 88.9794     | 39.4854       | 60.7176       | 22.7766       | 36.26         |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | +/-59.3938    | +/-84.2717  | +/-38.1342    | +/-36.8801    | +/-29.5259    | +/-35.2435    |     |
| Uterine Body                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | INVOLVED      | INVOLVED    | Not Involved  | INVOLVED      | Not Involved  | Not Involved  |     |
| INVOLVED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 149.0 ( 71%)  | 66.0 ( 97%) | 18.0 ( 43%)   | 66.0 (100%)   | 19.0 ( 38%)   | 0.0 (  0%)    |     |
| Not Involved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 68.0 ( 28%)   | 2.0 (  2%)  | 23.0 ( 56%)   | 0.0 (  0%)    | 31.0 ( 62%)   | 12.0 (100%)   |     |
| Status                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | No recurrence | RECURRENT   | No recurrence | No recurrence | No recurrence | No recurrence |     |
| RECURRENT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 82.0 ( 34%)   | 57.0 ( 83%) | 4.0 ( 14%)    | 9.0 ( 18%)    | 9.0 ( 18%)    | 1.0 (  2%)    |     |
| No recurrence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 155.0 ( 65%)  | 11.0 ( 16%) | 35.0 ( 86%)   | 57.0 ( 84%)   | 41.0 ( 82%)   | 11.0 ( 22%)   |     |
| Rel Primary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Rel Pelvic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |
| Rel Abdo                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Yes           | Yes         | Yes           | Yes           | Yes           | Yes           | Yes |
| Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 237.0 (100%)  | 68.0 (100%) | 41.0 (100%)   | 66.0 (100%)   | 50.0 (100%)   | 12.0 (100%)   |     |

Figure 7 shows the evaluation of attributes that outputs or yields the FIGO results. Though these characteristics are distinct from each other, but the combination of these distinct characters would yield a better result as regards the FIGO staging of a patients screening or diagnosis.

**Figure 7** Attribute selection output (FIGO) (see online version for colours)

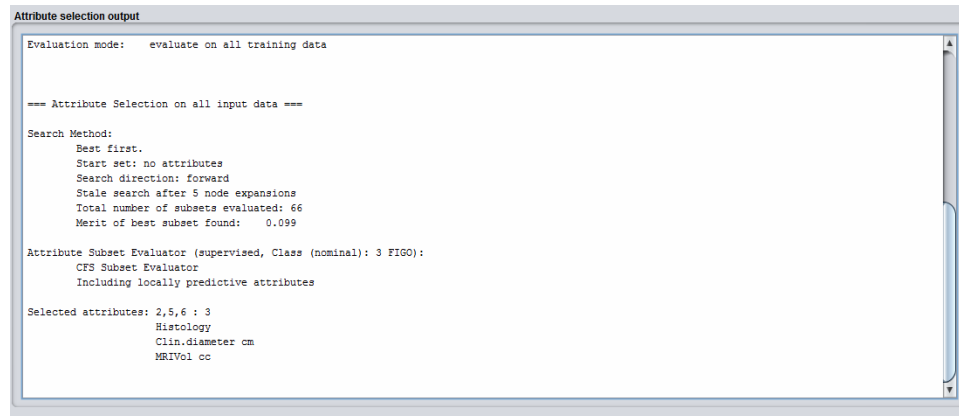


Figure 8 shows the relationship which were able to discover amongst data and group them together. Those relationship exist between histology, node pet, MRI vol and clin. diameter for the FIGO classification.

**Figure 8** Final cluster centroids

| Final cluster centroids:                                      |                      |             |             |             |             |             |             |             |  |
|---------------------------------------------------------------|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--|
| Attribute                                                     | Cluster#             |             |             |             |             |             |             |             |  |
|                                                               | Full Data<br>(237.0) | 0<br>(17.0) | 1<br>(39.0) | 2<br>(68.0) | 3<br>(21.0) | 4<br>(42.0) | 5<br>(23.0) | 6<br>(27.0) |  |
| Histology                                                     | 0.9241               | 0.3824      | 0.9487      | 0.9191      | 1           | 1           | 1           | 1           |  |
| nodePET +                                                     | 0.4515               | 0           | 1           | 1           | 0           | 0           | 0           | 0           |  |
| Clin.diameter cm                                              | 4.6203               | 4.1176      | 3.6538      | 5.7794      | 5.0238      | 4.0595      | 6.2174      | 2.6111      |  |
| MRIVol cc                                                     | 55.9106              | 45.5994     | 36.3059     | 89.1875     | 57.4114     | 27.8179     | 96.2278     | 15.1004     |  |
| Time taken to build model (full training data) : 0.02 seconds |                      |             |             |             |             |             |             |             |  |

#### 4.2 Fuzzy inference system

After similarities that determined accurate results were discovered, The phase of implementation was shifted from the WEKA's place of dwelling to MATLAB's domain – the language of technical computing. MATLAB having the ability to perform functions that uses fuzzy logic in modeling a system that uniquely represents a degree of truth using membership functions which ideally is the mapping between crisp value and fuzzy value. The method of transforming crisp values or principles into fuzzy value or significance is termed fuzzification.

For a system to be tagged interactive, the system ought to have an option whereby the user has room to give inputs to the system and also be able to receive respective feedback according to the inputs received from the user.

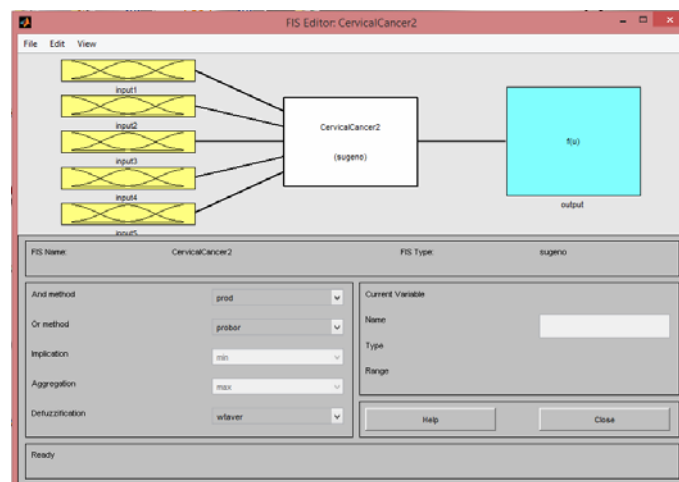
Figure 9 shows the parameters that were employed in this study. The system name is Cervical Cancer2, the type of inference method is Sugeno, MATLAB version 5, expected outputs, a single yielding outputs based on inputs, number of rules that helps in deciding the output, And method which is combination of several rules together, implementation method which is a product of the associated rules, aggregation method which is the sum of the rules and the defuzzification method which is Wtaver.

**Figure 9** Overview of the parameters employed

```
[System]
Name='CervicalCancer2'
Type='sugeno'
Version=2.0
NumInputs=5
NumOutputs=1
NumRules=243
AndMethod='prod'
OrMethod='probor'
ImpMethod='prod'
AggMethod='sum'
DefuzzMethod='wtaver'
```

Figure 10 illustrates the architecture of the Fuzzy Inference System used for this work. The fuzzy inference editor was used to map three (3) separate variables together which are input, Sugeno inference method and output. In Figure 11, the numbers of inputs were narrowed down to five (5) parameters. Each input has a range value and three (3) defined membership function attached to it. Inputs 1, 2, 3, 4 and 5 has a common range value between minimum value zero (0) and maximum value one (1), and the range of their membership value is between  $-219.823575$  and  $+848.209075$ . Figure 12 shows the rule table for the system.

**Figure 10** Architecture of the fuzzy inference system (see online version for colours)



**Figure 11** Inputs and their respective membership function

```

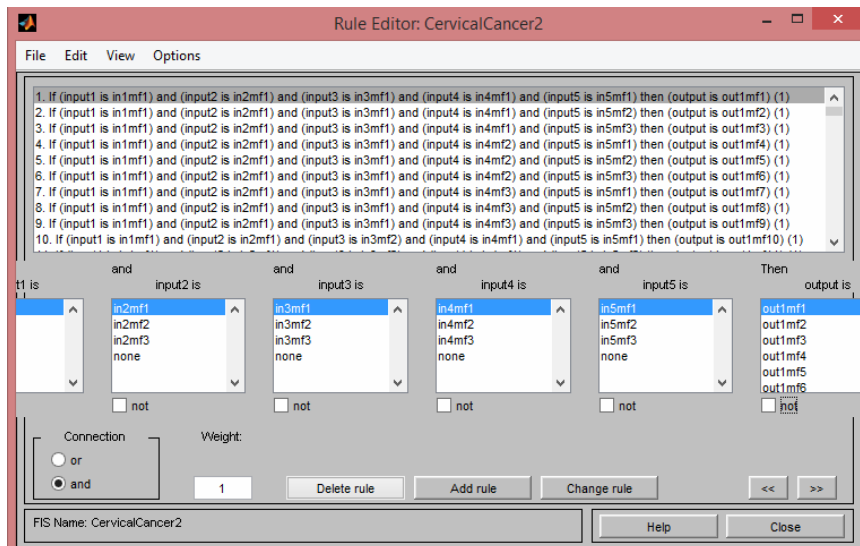
[Input1]
Name='input1'
Range=[0 1]
NumMFs=3
MF1='in1mf1':'trapmf',[-0.35 -0.15 0.15 0.35]
MF2='in1mf2':'trapmf',[0.15 0.35 0.65 0.85]
MF3='in1mf3':'trapmf',[0.65 0.85 1.15 1.35]

[Input2]
Name='input2'
Range=[0 1]
NumMFs=3
MF1='in2mf1':'trapmf',[-0.35 -0.15 0.15 0.35]
MF2='in2mf2':'trapmf',[0.15 0.35 0.65 0.85]
MF3='in2mf3':'trapmf',[0.65 0.85 1.15 1.35]

[Input4]
Name='input4'
Range=[0.0655 628.32]
NumMFs=3
MF1='in4mf1':'trapmf',[-219.823575 -94.172675 94.3041078000076 219.954700461323]
MF2='in4mf2':'trapmf',[94.1859522733648 219.95500424546 408.430925 534.081825]
MF3='in4mf3':'trapmf',[408.430925 534.081825 722.558175 848.209075]

[Input5]
Name='input5'
Range=[0 1]
NumMFs=3
MF1='in5mf1':'trapmf',[-0.35 -0.15 0.15 0.35]
MF2='in5mf2':'trapmf',[0.15 0.35 0.65 0.85]
MF3='in5mf3':'trapmf',[0.65 0.85 1.15 1.35]

```

**Figure 12** The rule table (see online version for colours)

These are deducted from the initial database. Parameters given to the system associates with these rules to yield an output . All the outputs for the 236 instances of queries which were generated using the fuzzy inference system are shown below.

---

| S/N, Input 1, Input2, Input3, Input4, Input5, Output(FIGO) |
|------------------------------------------------------------|
| 1,0,0,8,146.608,11.5,1.5                                   |
| 2,0,1,6,82.3727,11.5,1.5                                   |
| 3,0,0,2,5.9376,1.5,0.464                                   |
| 4,0.5,0,4,42.4116,11.5,1.65                                |
| 5,0.5,0,2,2.3562,1.5,0.522                                 |
| 6,0.5,0,2,4.1888,1.5,0.501                                 |
| 7,0.5,0,3,9.4248,1.5,2.41                                  |
| 8,0.5,1,6,109.956,11.5,2.2                                 |
| 9,0.5,1,3,5,20.2738,11.5,1.61                              |
| 10,0.5,1,6,86.394,11.5,2.56                                |
| 11,0.5,0,2,16.0222,1.5,0.366                               |
| 12,0.5,0,6,130.9,11.5,1.5                                  |
| 13,1,0,3,5,14.1372,11.5,1.9                                |
| 14,1,0,6,94.248,11.5,2.55                                  |
| 15,1,0,5,269.5493,11.5,1.51                                |
| 16,1,0,4,70.686,11.5,2.39                                  |
| 17,1,0,1,18.8496,11.5,1.5                                  |
| 18,1,0,3,5,33.9293,11.5,2.02                               |
| 19,1,0,4,5,30.2693,11.5,2.14                               |
| 20,1,0,4,26.3894,11.5,2.11                                 |
| 21,1,0,3,19.0852,11.5,2.15                                 |
| 22,1,0,4,1.5268,11.5,1.96                                  |
| 23,1,0,3,4.2281,11.5,2.23                                  |
| 24,1,1,3,25.1328,11.5,2.39                                 |
| 25,1,1,5,61.5754,11.5,2.61                                 |
| 26,1,1,5,65.9736,11.5,2.61                                 |
| 27,1,1,5,65.45,11.5,2.61                                   |
| 28,1,1,4,67.45444,11.5,2.18                                |
| 29,1,1,6,73.304,11.5,2.73                                  |
| 30,1,1,4,5,37.6992,11.5,2.73                               |
| 31,1,1,3,16.4934,11.5,2.02                                 |
| 32,1,1,4,64.7955,11.5,2.18                                 |
| 33,1,1,3,25.1328,11.5,2.39                                 |
| 34,1,1,4,50.2656,11.5,2.17                                 |
| 35,1,0,3,14.1372,1.5,2.18                                  |
| 36,1,0,3,25.6564,1.5,2.12                                  |
| 37,1,0,4,18.8496,1.5,2.07                                  |

---

---

38,1,0,5,8.7965,1.5,2.28  
39,1,0,7,31.3375,1.5,2.64  
40,1,0,3,11.781,1.5,2.19  
41,1,0,3,5.4193,1.5,2.24  
42,1,0,3,2.3677,1.5,2.24  
43,1,0,4,23.562,1.5,2.09  
44,1,0,3,21.9912,1.5,2.14  
45,1,0,4,18.8496,1.5,2.07  
46,1,1,4,21.9912,1.5,2.16  
47,1,1,5,22.1483,1.5,2.59  
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61,1,0,3,62.832,11.5,1.92  
62,1,1,6,79.5218,11.5,2.76  
63,1,1,5,47.124,11.5,2.6  
64,1,0,4,50.2656,11.5,2.26  
65,1,0,7,74.2203,11.5,1.52  
66,1,0,5,53.0145,1.5,2.55  
67,0,0,3,19.635,12,2  
68,0.5,0,4,30.5128,2,2.18  
69,0.5,1,4,41.888,12,2.09  
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71,1,0,4.5,42.4116,12,2.35  
72,1,0,6,47.124,12,2.88  
73,1,0,4.5,27.8555,12,2.26  
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75,1,0,4.5,9.8175,12,2.15  
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77,1,0,4,15.8667,12,2.05  
78,1,0,3.5,23.0908,12,1.96

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86,1,0,4,5,18.8496,2,2.2  
87,1,0,5,17.3416,2,2.33  
88,1,0,4,5,47.124,2,2.38  
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91,1,1,6,64.7955,2,2.69  
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95,1,1,3,18.8496,12,2.12  
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104,0.5,1,6,172.788,12.5,2.56  
105,0.5,1,5,70.2839,12.5,2.38  
106,0.5,0,6,21.9912,12.5,2.5  
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108,0.5,0,4,30.2379,12.5,2.19  
109,0.5,1,5,94.5496,12.5,2.59  
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111,1,0,6,58.6432,12.5,2.8  
112,1,0,4,11.4538,12.5,2.02  
113,1,0,4,5,16.0352,12.5,2.19  
114,1,0,4,18.8496,12.5,2.07  
115,1,0,5,5,78.54,12.5,2.82  
116,1,0,4,61.0518,12.5,2.33  
117,1,0,4,5,24.7401,12.5,2.24  
118,1,0,4,47.124,12.5,2.24  
119,1,0,4,43.9824,12.5,2.22

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125,1,0,6,89.2843,12.5,2.58  
126,1,0,5,42.3503,12.5,2.48  
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128,1,0,5,63.9284,12.5,2.62  
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130,1,0,8,153.9384,12.5,2.5  
131,1,0,4,47.124,12.5,2.24  
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134,1,1,3,25.5464,12.5,2.41  
135,1,1,3,14.1372,12.5,1.92  
136,1,1,4,62.832,12.5,2.18  
137,1,1,5,65.3453,12.5,2.61  
138,1,1,5,41.888,12.5,2.6  
139,1,1,6,58.6432,12.5,2.67  
140,1,1,7,77.1786,12.5,2.88  
141,1,1,5,37.6992,12.5,2.6  
142,1,1,4,30.1594,12.5,2.17  
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144,1,0,3,9.4248,2.5,2.21  
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160,1,0,4,5,23.562,12.5,2.23

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167,1,1,6,70.8431,12.5,2.72  
168,1,0,5,47.124,12.5,2.51  
169,1,1,4.5,73.5134,12.5,2.4  
170,1,1,6,131.9472,12.5,2.4  
171,1,1,6,142.9428,12.5,2.23  
172,1,1,3,14.1372,12.5,1.92  
173,1,0,5,153.9384,12.5,2.4  
174,1,0,6,65.9736,2.5,2.75  
175,1,0,3,41.888,12.5,2.03  
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180,1,0,3,14.6608,3,2.18  
181,1,0,3,6.2832,3,2.22  
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183,1,0,5,38.2019,13,2.46  
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185,0,0,4,86.394,13.5,3.5  
186,0.5,1,6,72.8851,13.5,3.11  
187,0.5,1,4,6.7544,3.5,0.469  
188,0.5,0,7,163.3632,13.5,3.5  
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209,1,1,7,94.248,13.5,3.05  
210,1,1,8,87.9648,13.5,3.52  
211,1,1,6,102.102,13.5,2.74

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212,1,1,6,29.5562,13.5,2.55  
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 215,1,0,5,33.5104,3.5,2.43  
 216,1,0,6,80.5381,3.5,2.64  
 217,1,1,3,31.416,13.5,2.66  
 218,1,1,5,37.4871,13.5,2.66  
 219,1,1,6,76.5765,13.5,2.74  
 220,1,1,5,47.713,13.5,2.6  
 221,1,1,6,88.3575,13.5,2.79  
 222,1,1,8,628.32,13.5,3.5  
 223,1,1,5,94.248,13.5,2.62  
 224,1,0,6,28.6702,13.5,3.02  
 225,1,1,4,51.8364,13.5,2.17  
 226,1,1,4,41.888,13.5,2.17  
 227,1,1,4,119.119,13.5,3.42  
 228,1,1,5,71.995,13.5,2.61  
 229,1,1,7,141.372,13.5,2.81  
 230,1,1,5,47.124,13.5,2.6  
 231,1,1,6,92.9285,13.5,2.81  
 232,1,1,6,70.686,13.5,2.72  
 233,1,0,5,51.0615,13.5,2.54  
 234,1,1,8,251.328,13.5,3.3  
 235,1,0,5,142.9533,3.5,2.5  
 236,1,1,6,53.0145,14,2.65

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The output is as a result of the association between the inputs and the rules that have been defined. The rules are known as the membership function. A total of 236 membership function or rules as you might prefer was depicted and used as a guideline for determining the resulting output of an input.

Rule 2 outputs stage 1b of cervical cancer.

Rule 8 outputs stage 2a

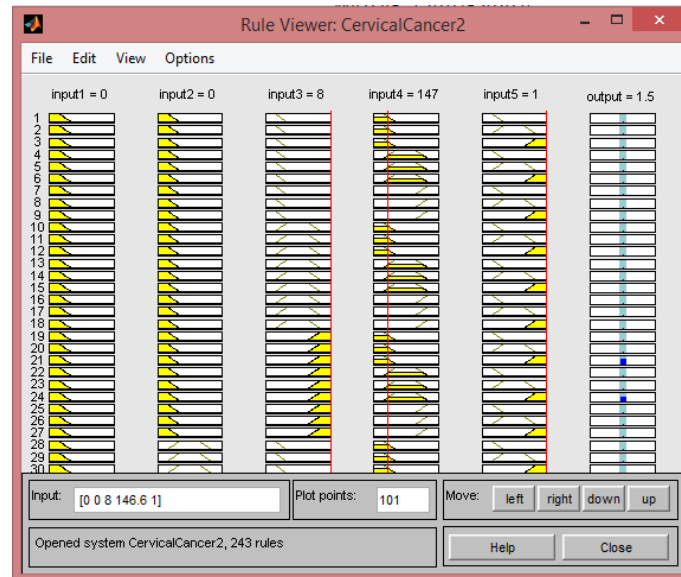
Rule 72 outputs stage 2b

Rule 177 outputs stage 3a

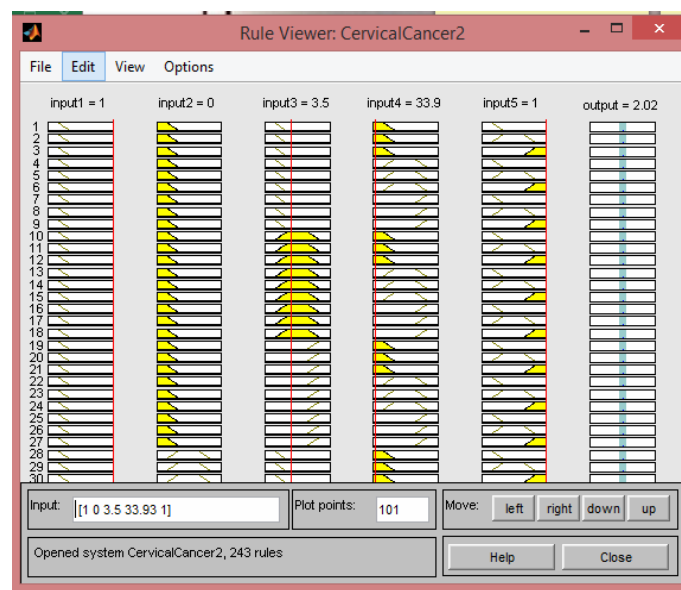
Rule 202 outputs stage 3b

Figures 13(a), 13(b), 13(c), 13(d) and 13(e) illustrates the outputs generated by the rules respectively.

**Figure 13** Rules, (a) rule 2 outputs stage 1b of cervical cancer (b) rule 8 outputs stage 2a (c) rule 72 outputs stage 2b (d) rule 177 outputs stage 3a (e) rule 202 outputs stage 3b (see online version for colours)

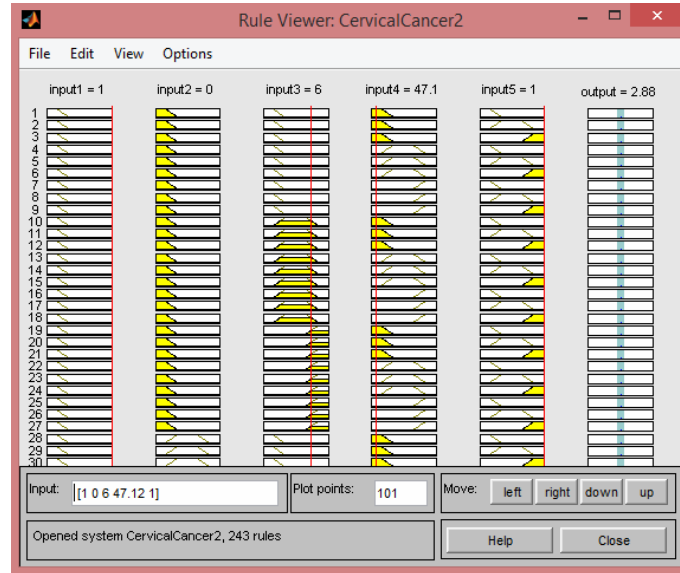


(a)

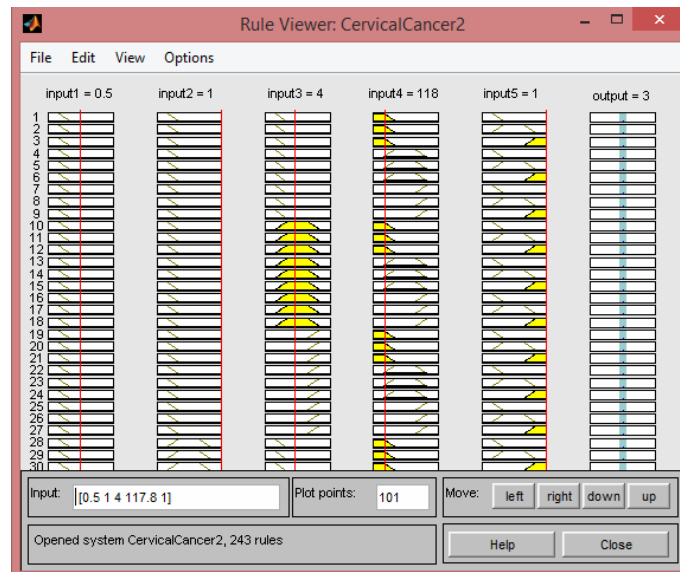


(b)

**Figure 13** Rules, (a) rule 2 outputs stage 1b of cervical cancer (b) rule 8 outputs stage 2a (c) rule 72 outputs stage 2b (d) rule 177 outputs stage 3a (e) rule 202 outputs stage 3b (see online version for colours) (continued)

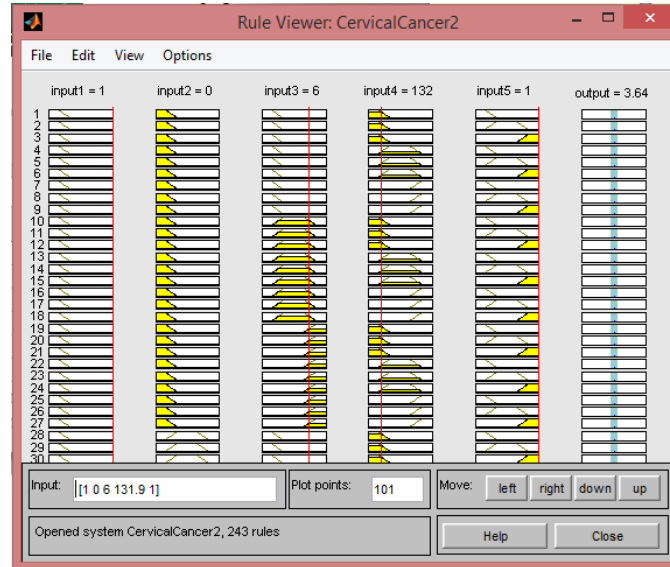


(c)



(d)

**Figure 13** Rules, (a) rule 2 outputs stage 1b of cervical cancer (b) rule 8 outputs stage 2a (c) rule 72 outputs stage 2b (d) rule 177 outputs stage 3a (e) rule 202 outputs stage 3b (see online version for colours) (continued)



(e)

The histology has been narrowed down to 1 and 0.5 both representing squamous cell carcinoma (SCC) and endometroid as they both have the highest occurrences in the dataset.

The FIGO staging has been narrowed down from stage (I-III) of cervical cancer. For staging of cervical cancer to be compactable with FIGO staging, the fuzzy system group cases of diagnosis stage with respect to ranges. Below are the natural classes and boundary range of each class.

Results that range from:

1.0 to 1.49 are classified as stage 1A

1.5 to 1.99 are classified as stage 1B

2.0 to 2.49 are classified as stage 2A

2.5 to 2.99 are classified as stage 2B

3.0 to 3.49 are classified as stage 3A

3.5 to 3.99 are classified as stage 3B.

Stage 1A and stage 4 of cervical cancer was omitted, because of its staging ability and its impossibility to cure of stage 4 and also stage 1A is not that considered as a stage in the cervical world. More so if patients learn about their diagnosis being a stage 4 case, the result tends to affect them emotional being aware that their chances of survival are much more minimal compared to other stage. The node PET, uterine body and status results were converted from nominal data having values 'yes and no' to binary values '1 and 0'

respectively. The cases of occurrences in rel. primary, rel. pelvic, rel. abdo, rel. supraclav and rel. distance results were converted from 'yes' to '1'.

## 5 Conclusions

Expert medical system offers the ability of making a decision which is not bias in judgement but rather based on inputted inputs giving to the system. In many cases there have been issues of being diagnosed of stage 2B cancer which later turned out to be a stage IB cancer. This ridiculous mistake would be further avoided if decision is placed in the hands of a trained system other than a Human which tends to use his head and mind when making crucial decision.

This system can easily predict cervical cancer stage with good accuracy. It can be further enhanced and expanded. For predicting cervical cancer stage, 13 attributes are used, besides this, other attributes which will have effect on results such as reoccurrence and status can be used. It also provides the training tool for nurses and medical students to predict patient having cervical cancer.

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