

classification and regression trees (CART). However, since parts of attributes can only be used to determine specific classes, the accuracy of the aforementioned classification method is decreased. The accuracy is probably decreased because of different combination of attributes selection, and lacks
5 of evaluating a performance of the discriminant analysis model.

Hence, it is desirable to provide a novel method for multi-layer classifier to solve the aforementioned problems.

SUMMARY OF THE INVENTION

Various embodiments seek~~The object of the present invention is to provide a method for~~
10 multi-layer classifier, which classifies the samples into 1 or 2 classes in each layer by selecting one or two cut-points. Furthermore, a linear combination of multiple attributes by the Fisher linear discriminant analysis can be used at each layer.

According to a first aspect, there is~~To achieve the object, the present invention~~
15 provides~~s~~ a method for multi-layer classifier, applying on a computer readable medium for classifying multiple image samples including a processor, an input device, and a storage device, the method at least comprising the following steps:

- (a) receiving a plurality of samples;
- (b) providing a plurality of attributes, and evaluating a significance
20 of the samples to the attributes by a selection criterion;
- (c) selecting at least one cut-point to establish a discriminant analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class in a current layer.

wherein the at least one class comprises a first class (Node_A), a second class (Node_B), and an undefined third class (Node_N);

(d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies the undefined class (Node_N) and the sample thereof into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and then continuously classifying the samples

into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and

(e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

According to a second aspect, there is provided a non-transitory computer readable medium storing a program to classify multiple image samples, by performing the steps of: (a) receiving a plurality of samples; (b) providing a plurality of attributes, and evaluating a significance of the samples to the attributes by a selection criterion; (c) selecting at least one cut-point to establish a discriminant analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class in a current layer, wherein the at least one class comprises a first class (Node_A), a second class (Node_B), and an undefined third class (Node_N); (d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies the undefined class (Node_N) and the sample thereof into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and then classifying the samples into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and (e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

Various embodiments~~The present invention also seek to~~ provides a computer readable medium for classifying multiple image samples, which storing a program to classify the multiple image samples by performing the method for multi-layer classifier therein, the computer readable medium including a processor, an input device, and a storage device.

determine the at least one cut-point of the residual samples.

Various embodimentsThe present invention provides a new classification method as
aforementioned, which has a model similar to the classification and
regression trees (CART), splitting the samples layer by layer. The
5 difference between the model of the present invention and CART is that the
model classifies the samples into 1 or 2 classes in each layer and the
unclassified samples left over to next layer for further classification. In
addition, a linear combination of multiple attributes by the Fisher linear
discriminant analysis can be used as the classifier at each layer. In order to
10 construct the classifier method, the present invention provides a systematic
methodology to select relevant attributes and proper cut-points. Adding the
attributes into the model will be evaluated by the full model's performance
to decide whether the model grows or not. To avoid the over-fitting problem,
the present invention proposes a stopping criterion. Furthermore, the
15 present invention also provides a method for selecting the attributes and
deciding the cut-points. Therefore, various embodimentsthe present invention can improve the
accuracy of the method for classifier.

Other objects, advantages, and novel features of the invention will
become more apparent from the following detailed description when taken
20 in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is a flow chart of the multi-layer discriminant analysis
method of the present invention;

FIG. 1b is a scheme of a multi-layer discriminant analysis mode

WHAT IS CLAIMED IS:

1. A method for multi-layer classifier, applying on a computer readable medium for classifying multiple image samples including a processor, an input device, and a storage device, the method at least
5 comprising the following steps:
 - (a) receiving a plurality of samples;
 - (b) providing a plurality of attributes, and evaluating a significance of the samples to the attributes by a selection criterion;
 - (c) selecting at least one cut-point to establish a discriminant
10 analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class, wherein the at least one class comprises a first class (Node_A), a second class (Node_B), and an undefined third class (Node_N);
 - 15 (d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of
20 the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and continuously classifying the samples into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and

(e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

2. The method as claimed in claim 1, wherein the number of the samples of the undefined third class (Node_N) is zero in the last layer of the discriminant analysis model when adding the stop criterion.

3. The method as claimed in claim 1 or 2, wherein the selection criterion is Wilk's lambda or Gini index.

4. The method as claimed in any one of claims 1 to 3, the step of evaluating the performance is based on a p-value calculated from a F-statistic, or is determined by a impurity criterion;

wherein the F-statistic represents as the following equation:

$$F = \frac{n-p-1}{p} \left(\frac{1-\Lambda}{\Lambda} \right) \sim F_{p, n-p-1},$$

wherein n is the sample size, p is the number of attributes, and Λ is Wilk's lambda (see EQ-1); and

the impurity criterion represents as the following equation:

$$\text{Impurity} = \frac{N_L \times \text{Gini}(t_L) + N_M \times \text{Gini}(t_M) + N_R \times \text{Gini}(t_R)}{(N_L + N_M + N_R)},$$

wherein N_L is the sample size of Node_A, N_M is the sample size of Node_N, N_R

is the sample size of Node_B, t_L is the gini value in Node_A, t_M is the gini value in Node_N, and t_R is the gini value in Node_B.

5 5. The method as claimed in any one of claims 1 to 4, wherein the attributes are ringPDVImax, VeinCentralVImin, VeinTDCentralVImax, TDVImax, CI, RMV, CI2, MCI3, or MI2.

6. The method as claimed in any one of claims 1 to 5, wherein the criterion to determine the at least one cut-point is Gini index, Mahalanobis distance, or Youden's Index.

10 7. The method as claimed in any one of claims 1 to 6, wherein the step of evaluating the performance further comprises: adding the attributes into the same layer of the discriminant analysis model established by the step (c), so that improves the differential power of the same layer of the discriminant analysis model.

15 8. The method as claimed in any one of claims 1 to 7, wherein the step of evaluating the performance further comprises: adding the attributes into the undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

20 9. The method as claimed in any one of claims 1 to 8, wherein the step of evaluating the performance further comprises: defining the first class (Node_A) as an undefined class, and then adding the attributes into the combination of the first class (Node_A) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously

classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

10. The method as claimed in any one of claims 1 to 9, wherein the
5 step of evaluating the performance further comprises: defining the second class (Node_B) as an undefined class, and then adding the attributes into the combination of the second class (Node_B) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined
10 third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

11. The method as claimed in any one of claims 1 to 10, wherein the regression analysis comprises a partial F-test of a forward selection method.

15 12. A computer readable medium storing a program to classify multiple image samples, by performing the steps of:

- (a) receiving a plurality of samples;
- (b) providing a plurality of attributes, and evaluating a significance of the samples to the attributes by a selection criterion;
- 20 (c) selecting at least one cut-point to establish a discriminant analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class, wherein the at least one class comprises a first class (Node_A), a second class

(Node_B), and an undefined third class (Node_N);

(d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and continuously classifying the samples into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and

(e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

13 The computer readable medium as claimed in claim 12, wherein the number of the samples of the undefined third class (Node_N) is zero in the last layer of the discriminant analysis model when adding the stop criterion.

14. The computer readable medium as claimed in claim 12 or 13, wherein the selection criterion is Wilk's lambda or Gini index.

15. The computer readable medium as claimed in any one of claims 12 to 14, the step of evaluating the performance is based on a p-value calculated from a F-statistic, or is determined by a impurity criterion; wherein the F-statistic represents as the following equation:

$$5 \quad F = \frac{n-p-1}{p} \left(\frac{1-\Lambda}{\Lambda} \right) \sim F_{p, n-p-1},$$

wherein n is the sample size, p is the number of attributes, and Λ is Wilk's lambda (see EQ-1); and

the impurity criterion represents as the following equation:

$$\text{Impurity} = \frac{N_L \times Gini(t_L) + N_M \times Gini(t_M) + N_R \times Gini(t_R)}{(N_L + N_M + N_R)},$$

10 wherein N_L is the sample size of Node_A, N_M is the sample size of Node_N, N_R is the sample size of Node_B, t_L is the gini value in Node_A, t_M is the gini value in Node_N, and t_R is the gini value in Node_B.

16. The computer readable medium as claimed in any one of claims 12 to 15, wherein the attributes are ringPDVImax, 15 VeinCentralVImin, VeinTDCentralVImax, TDVImax, CI, RMV, CI2, MCI3, or MI2.

17. The computer readable medium as claimed in any one of claims 12 to 16, wherein the criterion to determine the at least one cut-point is Gini index, Mahalanobis distance, or Youden's Index.

20 18. The computer readable medium as claimed in any one of claims 12 to 17, wherein the step of evaluating the performance further comprises: adding the attributes into the same layer of the discriminant

analysis model established by the step (c), so that improves the differential power of the same layer of the discriminant analysis model.

19. The computer readable medium as claimed in any one of claims 12 to 18, wherein the step of evaluating the performance further
5 comprises: adding the attributes into the undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

10 20. The computer readable medium as claimed in any one of claims 12 to 19, wherein the step of evaluating the performance further comprises: defining the first class (Node_A) as an undefined class, and then adding the attributes into the combination of the first class (Node_A) and undefined third class (Node_N) and creating a layer for establishing a model,
15 the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

21. The computer readable medium as claimed in claims 12 to 20, wherein the step of evaluating the performance further comprises: defining
20 the second class (Node_B) as an undefined class, and then adding the attributes into the combination of the second class (Node_B) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine

the at least one cut-point of the residual samples.

22. The computer readable medium as claimed in any one of claims 12 to 21, wherein the regression analysis comprises a partial F-test of a forward selection method.

CLAIMS

1. A method for multi-layer classifier, applying on a computer readable medium for classifying multiple image samples including a processor, an input device, and a storage device, the method at least comprising the following steps:

- (a) receiving a plurality of samples;
- (b) providing a plurality of attributes, and evaluating a significance of the samples to the attributes by a selection criterion;
- (c) selecting at least one cut-point to establish a discriminant analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class in a current layer, wherein the at least one class comprises a first class (Node_A), a second class (Node_B), and an undefined third class (Node_N);
- (d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies the undefined class (Node_N) and the sample thereof into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and then classifying the samples into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and
- (e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

2. The method as claimed in claim 1, wherein the number of the samples of the undefined third class (Node_N) is zero in the last layer of the discriminant analysis model when adding the stop criterion.

3. The method as claimed in claim 1, wherein the selection criterion is Wilk's lambda or Gini index.

4. The method as claimed in claim 1, the step of evaluating the performance is based on a p-value calculated from a F-statistic, or is determined by a impurity criterion;

wherein the F-statistic represents as the following equation:

$$F = \frac{n-p-1}{p} \left(\frac{1-\Lambda}{\Lambda} \right) \sim F_{p, n-p-1},$$

wherein n is the sample size, p is the number of attributes, and Λ is Wilk's lambda; and

the impurity criterion represents as the following equation:

$$\text{Impurity} = \frac{N_L \times \text{Gini}(t_L) + N_M \times \text{Gini}(t_M) + N_R \times \text{Gini}(t_R)}{(N_L + N_M + N_R)},$$

wherein N_L is the sample size of Node_A, N_M is the sample size of Node_N, N_R is the sample size of Node_B, t_L is the gini value in Node_A, t_M is the gini value in Node_N, and t_R is the gini value in Node_B.

5. The method as claimed in claim 1, wherein the criterion to determine the at least one cut-point is Gini index, Mahalanobis distance, or Youden's Index.

6. The method as claimed in claim 1, wherein the step of evaluating the performance further comprises: adding the attributes into the same layer of the discriminant analysis model established by the step (c), so that improves the differential power of the same layer of the discriminant analysis model.

7. The method as claimed in claim 1, wherein the step of evaluating the performance further comprises: adding the attributes into the undefined third class (Node_N) and creating a layer for

establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

8. The method as claimed in claim 1, wherein the step of evaluating the performance further comprises: defining the first class (Node_A) as an undefined class, and then adding the attributes into the combination of the first class (Node_A) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

9. The method as claimed in claim 1, wherein the step of evaluating the performance further comprises: defining the second class (Node_B) as an undefined class, and then adding the attributes into the combination of the second class (Node_B) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

10. The method as claimed in claim 1, wherein the regression analysis comprises a partial F-test of a forward selection method.

11. A non-transitory computer readable medium storing a program to classify multiple image samples, by performing the steps of:

- (a) receiving a plurality of samples;
- (b) providing a plurality of attributes, and evaluating a significance of the samples to the attributes by a selection criterion;
- (c) selecting at least one cut-point to establish a discriminant analysis model, which is established by providing a criterion to determine the at least one cut-point in one of the samples which is significant according to the step (b), and classifying the samples into at least one class in a current layer, wherein the at least one class comprises a first class (Node_A), a second class (Node_B), and an undefined third class (Node_N);

(d) proceeding a step of evaluating a performance of the discriminant analysis model when adding the attributes into the discriminant analysis model, wherein the discriminant analysis model further classifies the undefined class (Node_N) and the sample thereof into a next layer when the performance of the discriminant analysis model is improved by adding the attributes, and the next layer of the discriminant analysis model is established by providing the criterion to determine the at least one cut-point of the samples which is significant according to the added attributes, and then classifying the samples into the first class (Node_A), second class (Node_B), and undefined third class (Node_N); and
 (e) providing a stop criterion, in which the discriminant analysis model stops classifying into the next layer when there is no significant attributes can be found at next layer; or in which the discriminant analysis model stops classifying into the next layer when proceeding the step of evaluating the performance of the discriminant analysis model cannot be improved by adding the attributes to the discriminant analysis model under a condition of a rejected null hypothesis.

12. The computer readable medium as claimed in claim 11, wherein the number of the samples of the undefined third class (Node_N) is zero in the last layer of the discriminant analysis model when adding the stop criterion.

13. The computer readable medium as claimed in claim 11, wherein the selection criterion is Wilk's lambda or Gini index.

14. The computer readable medium as claimed in claim 11, the step of evaluating the performance is based on a p-value calculated from a F-statistic, or is determined by a impurity criterion;

wherein the F-statistic represents as the following equation:

$$F = \frac{n-p-1}{p} \left(\frac{1-\Lambda}{\Lambda} \right) \sim F_{p, n-p-1},$$

wherein n is the sample size, p is the number of attributes, and Λ is Wilk's lambda; and the impurity criterion represents as the following equation:

$$\text{Impurity} = \frac{N_L \times \text{Gini}(t_L) + N_M \times \text{Gini}(t_M) + N_R \times \text{Gini}(t_R)}{(N_L + N_M + N_R)},$$

wherein N_L is the sample size of Node_A, N_M is the sample size of Node_N, N_R is the sample size of Node_B, t_L is the gini value in Node_A, t_M is the gini value in Node_N, and t_R is the gini value in Node_B.

15. The computer readable medium as claimed in claim 11, wherein the criterion to determine the at least one cut-point is Gini index, Mahalanobis distance, or Youden's Index.

16. The computer readable medium as claimed in claim 11, wherein the step of evaluating the performance further comprises: adding the attributes into the same layer of the discriminant analysis model established by the step (c), so that improves the differential power of the same layer of the discriminant analysis model.

17. The computer readable medium as claimed in claim 11, wherein the step of evaluating the performance further comprises: adding the attributes into the undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

18. The computer readable medium as claimed in claim 11, wherein the step of evaluating the performance further comprises: defining the first class (Node_A) as an undefined class, and then adding the attributes into the combination of the first class (Node_A) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

19. The computer readable medium as claimed in claim 11, wherein the step of evaluating the performance further comprises: defining the second class (Node_B) as an undefined class, and

then adding the attributes into the combination of the second class (Node_B) and undefined third class (Node_N) and creating a layer for establishing a model, the model continuously classifies into the first class (Node_A), second class (Node_B), and undefined third class (Node_N) by providing the criterion to determine the at least one cut-point of the residual samples.

20. The computer readable medium as claimed in claim 11, wherein the regression analysis comprises a partial F-test of a forward selection method.