Raag detection in music using supervised machine learning approach

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Abstract
There are several research work is in progress in the direction of Raag detection. Raag is one of the melodic modes used in traditional South Asian music genres such as Indian classical music and qawwali. It can be said that Indian classical music is always set in a rāga. Non-classical music such as popular Indian film songs and ghazals sometimes use raagas in their compositions. There are several obstacles in accurate Raag detection technique. The major challenges are the complex parameters like pitch and mood in the music, skipping extra tones, conversion of different data attributes and Raag tempo. In this paper different classifiers like Bayesian net, naïve Bayes, support vector machine (SVM), J48, decision table, random forest, multi-layer perceptron and PART performance are analyzed. The music features are extracted using MIRToolbox in MATLAB. These extracted features are arranged in .arff file format. WEKA tool is used. The results shown below clearly indicate that the accuracies of all the classifiers after the discretization have increases considerably. While the accuracy of the probability based classifier are best in this Raag detection from music.

Keywords
Raag, Thaats, Naïve bayes, Decision tree, Support vector machine (SVM).

1. Introduction
In the ancient times music is the heart of India and the other countries. The root of Indian classical music is very rich. It includes many gharana and the different style and tradition for those gharana. Bhatkhande [1] describes the culture of these gharana and their music forming methods. Indian classical music can be categorized into two main streams like North Indian and South Indian based music and styles. Raag is essential building blocks in Indian classical music. Melodic mode of music comprises of five to nine musical notes is also termed as Raag.

In the recent past there are several works have been done on musical analysis and specially the Indian classical music, generating lot of new insight into this domain. The research related to musical information retrieval is thus attracting the interest of so many researchers. The music is categorized in different thaats based on which the ragas are derived. Different Distributions of notes making different note structures are called thaats.

The Latest research methods and techniques are focusing on carnatic raga and its analysis.

The music research and its analysis play an important role in finding the raga patterns on various ways. To identify their variety the thaat categorization is available in [1]. It is a system that is very relevant with this type of categorization. In 2013, Sharma et al. [2] proposed that thaats are classified in 10 different ways which are as follows: Bilawal, kalian, Todi, Bhairavi, Marwa, Kafi, Bhairav, Khamaj, Purvi, Asavari. These Thaats (raags) possess very different structural patterns so they can be distinguishingly identifiable [1].

2. Related work
In 2013 Chordia et al. [3] found that how the raga and the tonic are both mutually attached to each other. In their study they introduced some technique to identify the raga by the histogram approach and the Hidden markov model technique. The various studies in the same field discussed. There results suggest that the tonal features based on pitch distributions are robust, reliable features that can be applied to complex melodic music. In 2002, Tzanetakis [4] has also proposed various schemes in the English music classification based on their moods and styles of the performer as well as songs genre classification. Clustering is suggested as the classifier [5]. Sentiment analysis of movie review based on naïve Bayes and genetic algorithm is suggested in [6]. Since this methodology depends on the
likelihood it can be connected to a wide assortment of spaces and results can be utilized as a part of numerous ways [6]. It doesn't require expansive measure of information before preparing to start. These calculations are computationally quick to settle on choices [7]. SVM classifier which finds a hyperplane that clearly separates the sample points of different labels [8]. It divides such that sample points of both labels and class are on different sides of hyperplane. Decision tree and image processing techniques are suggested as the efficient classifier in [9, 10]. Mi Classifier: It is denoted as multi-instance classifiers. It comprises of numerous occasions in an illustration, yet perception of one class is conceivable just for every one of the examples [11]. Super-set and sub-set approach is suggested in [12]. Log file based classifier was suggested in [13]. Bayes net is a widely used technique which takes at the essential Bayes hypothesis and structures a Bayesian system in the wake of computing restrictive likelihood on each hub. It is a graphical model which is probabilistic in nature and depicts a gathering of discretionary variables alongside their restrictive conditions through a coordinated non-cyclic chart [14]. Logistic system utilizes relapse to anticipate the likelihood of a result which can have just two qualities. One or a few indicators are utilized to make the expectation [15]. Image based keying (IBK) remains for occurrence based information representation of the preparation cases and does not close or foresee a standard set or a choice tree [16]. JRip system executes a proposed guideline learner and aggregate blunder pruning strategy to diminish mistake. It depends on affiliation rules with diminished blunder pruning methods, in this way making it a powerful strategy [17]. PART utilizes a separation and vanquishes way to deal with build a C4.5 decision tree in part for every cycle indicating the ideal guideline affiliation. Utilizing an entropic separation measure strategy, it performs occurrence based learning. J48 is an upgraded variant of C 4.5 which spins on the ID3 calculation with some additional usefulness to determine issues that ID3 was clumsy [18]. Classification based on neural network is suggested in [19]. Mood based Bollywood music classification is suggested in [20]. In [22-24] a segmentation of phrases through identification of nyas and computes similarity with the reference characteristic phrase has been proposed. Table 1 shows the limitations in the existing techniques.

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Authors</th>
<th>Classifier</th>
<th>Category</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chakraborty et al. [25]</td>
<td>Naive Bayes</td>
<td>Probability based classifier</td>
<td>This is a probability based classifier based on Naive Bayes conditional probability. It fails on no occurrences of classes.</td>
</tr>
<tr>
<td>2.</td>
<td>Chakraborty et al. [25]</td>
<td>Bayesian Net</td>
<td>Probability based classifier</td>
<td>This is a probability based classifier based on Naive Bayes conditional probability. It only predicts based on the posterior information.</td>
</tr>
<tr>
<td>3.</td>
<td>Roy et al. [26]</td>
<td>J48</td>
<td>Tree approach based</td>
<td>It is enhanced version of C 4.5 algorithm and used ID3. Its reliability is only on the precise internal and external data feeding.</td>
</tr>
<tr>
<td>4.</td>
<td>Roy et al. [26]</td>
<td>Random Forest</td>
<td>Tree approach based</td>
<td>It is also a decision tree based approach but have more accuracy as compared to J48.</td>
</tr>
<tr>
<td>5.</td>
<td>Roy et al. [26]</td>
<td>Random Tree</td>
<td>Tree approach based</td>
<td>It generates a tree by randomly selecting branches from a possible set of trees.</td>
</tr>
<tr>
<td>6.</td>
<td>Gómez et al. [27]</td>
<td>REPTree</td>
<td>Tree approach based</td>
<td>It uses gain and variance for prediction. But fails in the case of no variance.</td>
</tr>
</tbody>
</table>
3. Problem statements

After studying several research works the following gaps have been analyzed in the previous techniques.
1. Key phrases identification is important as it is capable in extracting the maximum instances.
2. The attributes considered should be compared with social behaviors also.
3. Pitch and mood identification can be used as the training subset.
4. Compositions with similar patterns and dissimilar patterns should be identified separately.
5. Segmentation of the signal should be detected at the same frequency.

4. Proposed work

In this work features of the music are extracted using MIRToolbox in MATLAB. These extracted features are arranged in arff file format. WEKA tool is used, which is a machine learning tool works on the arff
file format. The Raag detection is performed on the musical file from which features are extracted. The following classifiers are used for Raag detection:

- Bayesian net
- Naive Bayes
- Support vector machine (SVM)
- J48
- Decision table
- Random forest
- Multi-layer perceptron
- PART

Accuracy of all the classifiers is calculated along with precision and recall. Then discretization is applied on dataset and then again all the classifiers are applied. The accuracy of classifiers before and after discretization is compared.

Following features are extracted from the music file:

- Centroid
- Flatness
- Entropy
- Tempo
- SwaraMean
- AvgPitch

The last attribute is the label which will hold the class of the Raag to which music file belongs. Label may be Bhairav, Yaman, Shanakara and Saarang. Figure 1 shows the generalized approach for the Raag classification. Description of basic audio operations, data output and analytical operators mechanism along with the feature values in arff file format is shown in Figure 2, which shows the flowchart of the method presented.

Figure 1 Generalized approach for Raag classification

Figure 2 Flowchart
Algorithms used in our proposed approach are to be discussed in the below sections:
- Multi-layer perceptron
- PART

**Algorithm 1: Bayesian net**
Step 1: A set of random variables to complete a cycle of a raag set.
Step 2: An arrangement of coordinated connections associates sets of hubs. The instinctive importance of a bolt from hub X to hub Y is that X affects Y.
Step 3: Each node has a conditional probability table (CPT) that evaluates the impacts that the guardians have on the hub. The guardians of a hub X are every one of those hubs that have bolts indicating X.
Step 4: It shows the exponentially sized joint probability distribution (JPD).
Each section in the JPD can be processed from the data in the BN by the chain
\[ P(b \mid a) = \frac{P(a \mid b) \ast P(b)}{P(a)} \]

**Algorithm 2: Support vector machine (SVM)**
Goal: 1) Correctly classify all training data
   - if \( y_i = +1 \)
   - if \( y_i = -1 \)
   for all i
2) Maximize the margin same as minimize
   \[ M = \frac{2}{\sqrt{w'w}} \]
3) We can formulate a Quadratic Optimization Problem and solve for w and b
Minimize
\[ \Phi(w) = \frac{1}{2} w' w \]
subject to \( y_i (w x_i + b) \geq 1 \quad \forall i \)

**Algorithm 3: Decision Tree**
Takes an arrangement of characterized cases and a rundown of properties, atts. Gives back the root hub of a choice tree
Make hub N;
On the off chance that cases are all in same class
At that point RETURN N marked with that class;
On the off chance that atts is vacant
At that point RETURN N marked with modular case class;
best_att = choose_best_att(examples,atts);
mark N with best_att;

**Algorithm 4: Random forest**
Step 1: Every tree is developed utilizing the accompanying calculation:
Step 2: Give the quantity of preparing cases a chance to be N, and the quantity of variables in the classifier be M.
We are told the number m of information variables to be utilized to decide the choice at a hub of the tree; m ought to be a great deal not as much as M.
Pick a preparation set for this tree by picking n times with substitution from all N accessible preparing cases (i.e. take a bootstrap test). Utilize whatever is left of the cases to gauge the blunder of the tree, by foreseeing their classes.
For every hub of the tree, arbitrarily pick m variables on which to base the choice at that hub. Figure the best split in view of these m variables in the preparation set. Every tree is completely developed and not pruned (as might be done in building a typical tree classifier).
For expectation another example is pushed down the tree. It is doled out the mark of the preparation test in the terminal hub it winds up in. This methodology is iterated over all trees in the group, and the normal vote of all trees is accounted for as irregular woods forecast.

**Algorithm 5: Multi-layer perceptron**
Step 1: Initialize weights randomly, pick a learning rate \( \eta \)
Until system is prepared:
For every preparation illustration i.e. info example and target output(s):
Step 2: Do forward go through net (with settled weights) to deliver output(s)
i.e., in Forward Direction, layer by layer:
Inputs connected
Increased by weights
Summed "combined" by sigmoid enactment capacity
Step 3: Yield went to every neuron in next layer
Rehash above until system output(s) created.

Compute delta or neighborhood angle for each
yield unit δ

Layer-by-layer, register mistake (delta or nearby
angle) for each concealed unit δ by backpropagating
error (as indicated beforehand)

Step 4: Next, overhaul every one of the weights Δwij
By slope plummet, and do a reversal to Step 2

The general MLP learning calculation, including
forward pass and backpropagation of blunder (until
the system preparing finish), is known as the
Generalized Delta Rule (GDR), or all the more
usually, the Back Propagation (BP) calculation.

Step 5: This was a solitary cycle of back-propagation
preparing requires numerous cycles with numerous
preparation cases or ages (one age is whole
presentation of complete preparing set). It can be
moderate. Note that calculation in MLP is
neighbourhood (as for every neuron).

Step 6: Parallel calculation usage is likewise
conceivable.

5. Results and analysis
A tool which is used for both Data mining and
Machine Learning is WEKA. It was first
implemented by The University of Waikato, New
Zealand, in 1997. It is a collection of an enormous
number of Machine Learning and Data Mining
algorithms. One drawback of this software is that it
supports data files only written in ARFF (attribute
relation file format) and CSV (comma separated
values) format. Initially, it was written in C but later
on it was rewritten in JAVA language. It comprises
of a GUI interface for interaction with the data files.
It possesses 49 data pre-processing tools, 15 attribute
evaluators, 76 classification algorithms and 10 search
algorithms for the purpose of feature selection. It
comprises of three different types of graphical user
interfaces (GUI’s):- “The Explorer”, “The
Experimenter”, and “The Knowledge Flow”. WEKA
provides the opportunity for the development of any
new Machine Learning algorithm. It contains
visualization tools and a set of panels to execute the
desired tasks.

Weka has user friendly GUI and is used widely by
majority of the users working in the field of machine
learning. In this work of Raag detection in music
other tools like MIRToolbox are also used to extract
features from the music that’s why instead of writing
codes and using inbuilt libraries for machine learning
Weka is used here. Classification algorithms or
classifiers are used to basically sort out the network
traffic into normal and anomaly categories. The
objective behind classification techniques is to
achieve high accuracy and precision and to classify
the objects.

Classifiers can be broadly classified into eight types
in WEKA, where various machine learning
algorithms reside in each category.

A series of experiments have been conducted to
compare different supervised learning techniques for
Raag detection. Different existing techniques are
considered for comparing the ability and efficiency of
detecting the variants of Raag detection techniques
with these existing techniques. Then precision and
recall for all the classifiers are calculated. Precision
and recall are interpreted concerning the retrieval and
the set of relevancy in those retrieval items are
relevance. Numerically these are defined as follows:

Precision = \( \frac{True \ positive}{True \ positive + False \ positive} \)

Recall = \( \frac{True \ positive}{True \ positive + False \ negative} \)

The results of different classifiers for precision and
recall have been shown in the below tables. The
results are shown in Table 2-Table 11.

(a) Bayesian Net

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True positive</th>
<th>False positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.680</td>
<td>0.0040</td>
<td>0.850</td>
<td>0.680</td>
</tr>
<tr>
<td>Yaman</td>
<td>0.880</td>
<td>0.013</td>
<td>0.957</td>
<td>0.880</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.720</td>
<td>0.147</td>
<td>0.621</td>
<td>0.720</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.600</td>
<td>0.173</td>
<td>0.536</td>
<td>0.600</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.720</td>
<td>0.093</td>
<td>0.741</td>
<td>0.720</td>
</tr>
</tbody>
</table>
(b) Naive Bayes

Table 3 Precision and recall in case of naive BAYES

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.680</td>
<td>0.067</td>
<td>0.773</td>
<td>0.680</td>
</tr>
<tr>
<td>Yaman</td>
<td>1.000</td>
<td>0.027</td>
<td>0.926</td>
<td>1.000</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.840</td>
<td>0.160</td>
<td>0.636</td>
<td>0.840</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.480</td>
<td>0.080</td>
<td>0.667</td>
<td>0.480</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.750</td>
<td>0.083</td>
<td>0.750</td>
<td>0.750</td>
</tr>
</tbody>
</table>

(c) PART

Table 4 Precision and recall in case of PART

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.800</td>
<td>0.107</td>
<td>0.714</td>
<td>0.800</td>
</tr>
<tr>
<td>Yaman</td>
<td>0.880</td>
<td>0.053</td>
<td>0.846</td>
<td>0.880</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.800</td>
<td>0.160</td>
<td>0.625</td>
<td>0.800</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.240</td>
<td>0.107</td>
<td>0.429</td>
<td>0.240</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.680</td>
<td>0.107</td>
<td>0.654</td>
<td>0.680</td>
</tr>
</tbody>
</table>

(d) J48

Table 5 Precision and recall in case of J48

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.800</td>
<td>0.120</td>
<td>0.690</td>
<td>0.800</td>
</tr>
<tr>
<td>Yaman</td>
<td>0.880</td>
<td>0.053</td>
<td>0.846</td>
<td>0.880</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.760</td>
<td>0.147</td>
<td>0.633</td>
<td>0.760</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.320</td>
<td>0.093</td>
<td>0.533</td>
<td>0.320</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.690</td>
<td>0.103</td>
<td>0.676</td>
<td>0.690</td>
</tr>
</tbody>
</table>

The results shown below clearly indicate that the accuracies of all the classifiers after the discretization have increases considerably. While the accuracy of the probability based classifier are best in this Raag detection from music.

The graph shown in Figure 3 suggested that the accuracy of all the classifiers used is compared before and after discretization. Data discretization is defined as a procedure of changing over constant information property estimations into a limited arrangement of interims and taking up with every interim some particular information esteem. Figure 4 presented the comparative graph based on the result obtained and the previous results.

(e) Random Forest

Table 6 Precision and recall in case of Random Forest

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.600</td>
<td>0.067</td>
<td>0.750</td>
<td>0.600</td>
</tr>
<tr>
<td>Yaman</td>
<td>1.000</td>
<td>0.053</td>
<td>0.862</td>
<td>1.000</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.840</td>
<td>0.120</td>
<td>0.700</td>
<td>0.840</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.480</td>
<td>0.120</td>
<td>0.571</td>
<td>0.480</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.730</td>
<td>0.090</td>
<td>0.721</td>
<td>0.730</td>
</tr>
</tbody>
</table>

(f) Multi-layer perceptron Results

Table 7 Precision and recall in case of multilayer perceptron

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.560</td>
<td>0.080</td>
<td>0.700</td>
<td>0.560</td>
</tr>
<tr>
<td>Yaman</td>
<td>0.840</td>
<td>0.053</td>
<td>0.840</td>
<td>0.840</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.680</td>
<td>0.133</td>
<td>0.630</td>
<td>0.680</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.440</td>
<td>0.227</td>
<td>0.393</td>
<td>0.440</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.630</td>
<td>0.123</td>
<td>0.641</td>
<td>0.630</td>
</tr>
</tbody>
</table>

(g) Decision Table

Table 8 Precision and recall in case of decision table

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhairav</td>
<td>0.520</td>
<td>0.080</td>
<td>0.684</td>
<td>0.520</td>
</tr>
<tr>
<td>Yaman</td>
<td>1.000</td>
<td>0.040</td>
<td>0.893</td>
<td>1.000</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.880</td>
<td>0.213</td>
<td>0.579</td>
<td>0.880</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.240</td>
<td>0.120</td>
<td>0.400</td>
<td>0.240</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.660</td>
<td>0.113</td>
<td>0.639</td>
<td>0.660</td>
</tr>
</tbody>
</table>

(h) Support vector machine

Table 9 Precision and recall in case of SVM Results

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>True Positive</th>
<th>False Positive</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.850</td>
<td>0.680</td>
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<td>0.880</td>
</tr>
<tr>
<td>Shankara</td>
<td>0.720</td>
<td>0.147</td>
<td>0.621</td>
<td>0.720</td>
</tr>
<tr>
<td>Saarang</td>
<td>0.600</td>
<td>0.173</td>
<td>0.536</td>
<td>0.600</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.720</td>
<td>0.093</td>
<td>0.741</td>
<td>0.720</td>
</tr>
</tbody>
</table>

Table 10 Accuracies of all classifiers before and after discretization

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Accuracy (Before Discretization)</th>
<th>Accuracy (After Discretization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naive Bayes</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>SVM</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td>J48</td>
<td>69</td>
<td>75</td>
</tr>
</tbody>
</table>
### Table 11 Comparison with previous classification for Raag detection

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bayesian Net</td>
<td>83</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>Naïve Bayes</td>
<td>80</td>
<td>43.94</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
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<td>75</td>
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</table>

*NA: Not available

### Figure 3 Accuracy of all the classifiers

### Figure 4 Comparison with previous classification algorithms
6. Discussion and conclusions

There are several research works in progress in the direction of Raag detection. It is the unique sequence in music which comprises of five to nine musical notes in melodic music. It depends on the pitch of musical notes and the mood in which they are conveyed rather than the sequence of notes. Its accurate detection is helpful in generating correct and accurate Raag with the different musical instrument. There are several obstacles in accurate Raag detection technique. The major challenges are the complex parameters like pitch and mood in the music, skipping extra tones, conversion of different data attributes and Raag tempo. In this paper a study and analysis have been presented to stumble the gaps and finding the advantages of the previous approaches. The previous research suggests supervised and unsupervised learning both for raag detection. So this paper included the methods from above two for comparison. This study shows that the supervised learning is capable in improving the detection results.

In this paper eight classifiers like Bayesian net, naive Bayes, SVM, J48, decision table, random forest, multi-layer perceptron and PART are considered for musical instrument Raag detection. The results are compared before and after discretization. The results indicate that the accuracies of all the classifiers after the discretization have increases considerably. While the accuracy of the probability based classifier are better in this Raag detection from music. Bayesian Net provides better results in all of them.

Acknowledgment

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Conflicts of interest

The authors have no conflicts of interest to declare.

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