Creating Classifier Ensembles through Meta-heuristic Algorithms for Aerial Scene Classification

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Abstract

Convolutional Neural Networks (CNN) have been widely employed to solve the challenging remote sensing task of aerial scene classification. Nevertheless, it is not straightforward to find single CNN models that can solve all aerial scene classification tasks, allowing the development of a better alternative, which is to fuse CNN-based classifiers into an ensemble. However, an appropriate choice of the classifiers that will belong to the ensemble is a critical factor, as it is unfeasible to employ all the possible classifiers in the literature. Therefore, this work proposes a novel framework based on meta-heuristic optimization for creating optimized ensembles in the context of aerial scene classification. The experimental results were performed across nine meta-heuristic algorithms and three aerial scene literature datasets, being compared in terms of effectiveness (accuracy), efficiency (execution time), and behavioral performance in different scenarios. Our results suggest that the Univariate Marginal Distribution Algorithm shows more effective and efficient results than other commonly used meta-heuristic algorithms, such as Genetic Programming and Particle Swarm Optimization.

Framework for Building Classifier Ensemble

Experimental Setup

- **Three datasets:**
  - RSSLN7
  - WHU-RS19
  - UCMerced
- **Learning Methods:** We used six learning methods in the framework: Naive Bayes (NB), Decision Tree (DT), Naive Bayes (NB), Support Vector Machine (SVM), and $k$-Nearest Neighborhood ($k$NN) using $k = \{1, 3, 5, 7\}$. All implementations in the WEKA.
- **Global Descriptors:** BIC, CCV, GCH, QCCH, and LAS.
- **Deep Learning Features:** VGG16, VGG19, Inception-v3, Xception, and Resnet-50.
- **Evaluation Measure:** Accuracy, number of used classifiers, and time.
- **Experimental protocol:** 5-fold cross-validation protocol and all results are reported in terms of the average among five runs.

Classification Results

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Global (35)</th>
<th>CNN (35)</th>
<th>ALL (70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHU-RS19</td>
<td>74.8 (±1.0) 16</td>
<td>95.8 (±1.0) 17</td>
<td>93.9 (±1.5) 30</td>
</tr>
<tr>
<td>RSSLN7</td>
<td>69.6 (±1.0) 18</td>
<td>95.6 (±1.0) 17</td>
<td>93.9 (±1.5) 30</td>
</tr>
<tr>
<td>UCMerced</td>
<td>79.5 (±1.0) 15</td>
<td>99.2 (±0.7) 15</td>
<td>96.8 (±1.4) 15</td>
</tr>
</tbody>
</table>

Efficiency Results

<table>
<thead>
<tr>
<th>Dataset</th>
<th>WHU-RS19</th>
<th>RSSLN7</th>
<th>UCMerced</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHU-RS19</td>
<td>52.2 (±1.6) 9</td>
<td>2964 (±95) 9</td>
<td>2150 (±270) 9</td>
</tr>
<tr>
<td>RSSLN7</td>
<td>21.4 (±1.5) 7</td>
<td>1944 (±160) 7</td>
<td>1580 (±307) 8</td>
</tr>
<tr>
<td>UCMerced</td>
<td>79.5 (±1.0) 15</td>
<td>99.2 (±0.7) 15</td>
<td>96.8 (±1.4) 15</td>
</tr>
</tbody>
</table>

Conclusions

- All meta-heuristic algorithms achieved better classification results than baseline (MV).
- Optimization algorithms reduced the number of classifiers in the final ensembles by at least 49%.
- UMDA algorithm is at least ~1.4x faster than the most efficient optimization algorithm compared in this work.

Code is available on the Github https://github.com/gugarosa/evolutionary_ensembles