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An Entropy Driven Feature Selection Technique for Scene Text Classification using Crow Search Optimization

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Irrelevant and redundant features significantly degrade and impact classification performance in scene text recognition systems. Particularly, it becomes more impactful when handcrafted multimodal feature descriptor are employed for classification. Hence, this paper introduces framework including entropy driven Crow Search Optimization (CSO) for reducing high dimensionality of fused feature space and selecting salient features. The proposed technique formulates feature selection as a wrapper based naturally inspired optimization problem. The CSO in this work used to exploit social foraging behavior to iteratively refine feature subsets. A fitness function based on entropy computation is incorporated to quantify the feature information richness, discriminative behavior and relevance. The proposed framework is applied to serially fuse multimodal feature space generated from segmented Natural Scene Text (NST) images. These NST images are collected from challenging benchmark datasets SVT, MSRA-TD500 and KAIST. Extensive experiments demonstrate that the proposed framework significantly enhance the classification accuracy while reducing the computational overhead and false positives. The proposed framework is also compared against benchmark metaheuristic techniques including Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Ant Colony Optimization (ACO) in the same setup. Hence, the proposed framework confirms the stability, superiority and establish that entropy driven CSO as scalable and powerful feature selection strategy for complex scene text classification and recognition tasks.

1. Introduction

The performance of scene text classification is significantly dependent on the relevance and quality of extracted features. It becomes more impactful when multimodal feature approach is utilized rather than single feature model. Therefore, in recent times, the combination of handcrafted feature descriptors (geometric, appearance based, contour, texture) and/or deep features have been widely utilized. The purpose is to capture diverse visual characteristics of NST images (Akhtar et al., 2023; He et al., 2023; Hong et al., 2020; Kushwaha & Nain, 2020; Rassem & Khoo, 2014; Tan & Triggs, 2010). Whereas these descriptors sometimes extract complementary information and their combination mostly results in high dimensionality feature spaces consisting of irrelevant and redundant components. This fusion adversely affect computational efficiency and classification accuracy (Cui et al., 2019).

In this regard, optimal feature selection has emerged as a critical and essential step in improving the classification and recognition accuracy. This could only be achieved by identifying highly discriminative and salient features while discarding redundant and irrelevant information. Conventional, filter-based approaches heavily depend on statistical measures and often unable and fail to capture complex nonlinear dependencies among the features. The challenge is further aggravated in scene text classification where multimodal feature is usually employed to handle severe text appearances. To overcome these problems, wrapper-based approaches are there to evaluate feature subsets for classification performance. These are somehow computationally expensive but powerful in dealing with large feature spaces and impactful while selecting salient features as well (Adamu et al., 2021).

Therefore, naturally inspired metaheuristic optimization approaches have been increasingly becoming the recent researcher's choice. It is all because of their ability to explore complex search spaces efficiently based on natural phenomenon. Hence techniques including Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO) have proven themselves in various complex pattern recognition tasks and demonstrated promising results (Ahmed et al., 2021; Ansari et al., 2021; Ghosh et al., 2020). The core component of all these techniques is design and implementation of fitness function, which help them for convergence and decision about selection of salient features. However, sometime these methods suffer from limited exploration, exploitation balance premature convergence when applied to highly nonlinear and multimodal feature spaces.

Among these metaheuristic methods, the Crow Search Optimization (CSO) is a relatively recent discovery inspired by the intelligent foraging behavior of crows. This algorithm shows strong potential in cracking highly dimensional and well constrained optimization problems (Askarzadeh, 2016). Further, introducing adaptive awareness mechanisms and modeling memory based search CSO offers enhanced global investigation capabilities when compared with traditional optimization method.(Adamu et al., 2021; Ouadfel & Abd Elaziz, 2020). Despite its advantages, the application of CSO for salient feature selection in scene text classification is selected as first attempt to explore its impact and power.

To explore further this eminent gap this paper exclusively focused on getting optimal features from large feature space for scene text classification. Therefore, a novel wrapper technique is employed based on CSO. The proposed framework incorporates entropy driven fitness function

to select and rank salient features from multimodal feature space. The proposed pipeline aims to enhance the performance of classification by reducing the dimensionality and redundant information. Comprehensive experimentation demonstrates that novel CSO based optimization technique outperforms PSO, ACO, and GA under identical setup incorporating NST images from selected challenging NST datasets.

1.1 Research Contributions

The main contributions of this proposed framework are outlined below:

1. A novel wrapper-based feature selection pipeline is introduced (CSO) to address redundant and irrelevant extracted feature from large multimodal space
2. Entropy driven fitness function is used to select and rank the features
3. The proposed strategy is applied on fused feature space obtained from segmented binary NST images for effective reliability and generalization without loss discriminative information
4. Comparative analysis is conducted with benchmarks including PSO, ACO and GA
5. Experimental evaluation on MSRA-TD500, SVT and KAIST datasets highlights the eminence of proposed framework, which consistently improves in terms of stability and classification accuracy

1.2 Paper Structure

The remainder of paper is organized in multiple sections. Begins with **Section 2** review the related work followed by **Section 3** that reflect detail implementation of proposed pipeline. **Section 4** discusses the results and conclusion and future work is mentioned in **Section 5** to end this paper.

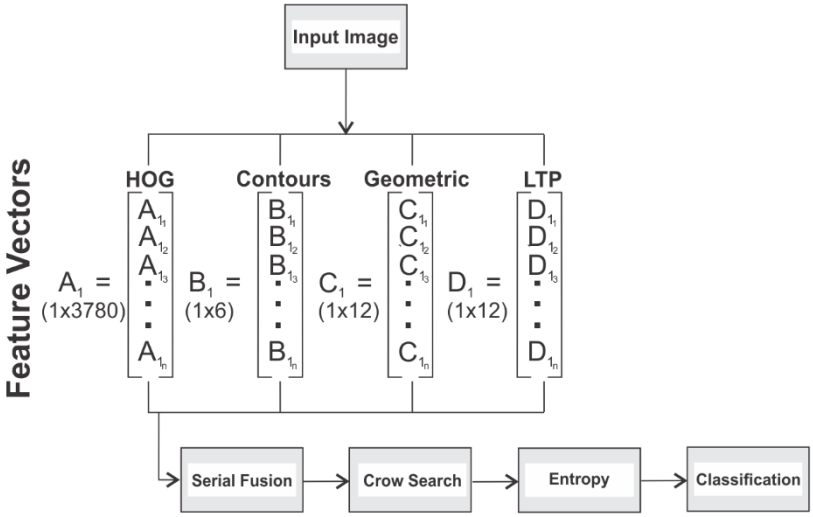
2. Literature Review

In modern classification pipelines feature selection and optimization remain crucial due to large feature dimensions. Since, it contains noisy, irrelevant and redundant information that increase the computational cost and degrade the generalization of classifiers. Recent works increasingly emphasize that feature selection as wrapper-based NP hard optimization problem. As metaheuristics requires to balance between exploitation and exploration to search compact but discriminative subsets (Jiang et al., 2024).

Now a days, mostly researchers show interest in crow search family optimizers due to their strong natural behavior. This includes foraging, flexibility and memory guided search behavior for binarized optimal subset feature selection. (Jiang et al., 2024), proposed a Dynamic Crow Search Algorithm (DCSA) to reduce high dimensionality for classification. The authors introduced dynamic strategies to enhance the convergence by transitioning between exploitation and exploration. They evaluated their selected subsets on wrapper classifiers. In another work (Osei-Kwakye et al., 2023), presented PSO-CSA diversity enhanced feature optimizer. They emphasize the population diversity control to decrease premature convergence of classifier followed by an issue reported when feature space is rugged and large in swarm optimizers. The proposed work supports the notion of adaptive movement behavior and controlling diversity to substantially enhance the optimal feature set stability and quality across all domains.

A parallel bunch of recent researchers underscores the multi strategy descriptors and richer perturbation methods in order to strengthen later stages refinement and global search. (Zhao et al., 2024), published a multi strategically augmented Harris Hawks optimization for optimal feature selection. The authors designed and employed collaboration, crossovers and communication inspired operators to improve solution robustness and solution on multiple datasets. Generally, the most recent works indicates three consistent flavors: (i) Meta/hybrid operators designs to prevent stagnation and enhance stability, (ii) crow search variants for selecting salient, optimal and compact feature subsets for classification performance, (iii) wrapper feature selection when priority is to maximize the classification generalization (Abdo et al., 2024).

Figure No 1: Proposed entropy driven CSO based feature optimization pipeline



Hence, the aforementioned literature motivated to present a novel work focusing simple wrapper based CSO feature selection combined with entropy driven fitness function. This work will be utilized in future to identify salient features from fused multimodal vector for different applications and research problems. Therefore, its aim is to overcome the limitations in existing optimization methods by enhancing classification accuracy and performance under challenging natural scenic conditions. The upcoming section highlights in this aspect the related proposed pipeline.

3. Methodology

The proposed CSO based pipeline is shown in Figure 1. Figure 1 depicts handcrafted feature extracted from binary segmented image as input. Then these features are serially fused to generate multimodal feature space. After that, CSO optimization is applied incorporating the entropy driven fitness function remove redundant, irrelevant information from fused space and finally fed to selected classifier to monitor increasing behavior and performance.

Figure No 2: Adjusted And Utilized Parameters for Proposed Optimization Pipeline

Parameter	Symbol	Value Used	Rationale / Impact
Population Size (number of crows)	*P*	30	A moderate population ensures adequate search diversity while avoiding unnecessary computational cost. Larger populations (>50) increased runtime without significant accuracy improvement.
Flight Length	*fl*	1.5	Controls the exploration step size. A value slightly >1 supports global exploration of feature space and prevents premature convergence.
Awareness Probability	*AP*	0.2	Low awareness probability encourages more aggressive searching (i.e., successful "stealing" of better feature subsets). Higher values (>0.4) led to slower convergence and suboptimal local traps.
Maximum Iterations	*itrmax*	80	Sufficient for algorithm convergence in trial runs. Increasing up to 150 iterations offered marginal gains at the cost of significantly more computation.
Fitness Function	—	Entropy-based relevance score	Encourages selection of non-redundant, high-information features to enhance discriminative performance.

1.1 Obtaining Optimal Feature Space using Entropy Drive CSO based Optimization

The dimension of obtained feature space after serial fusion is $[N \times 3810]$. The space might contain irrelevant and redundant information. This fused space undoubtedly mislead the classification generalization (Cui et al., 2019). Therefore, it is important to remove unnecessary and irrelevant features to reduce feature dimensionality. As a result, classification performance enhances and supplementary minimize computational time as well. Hence, wrapper-based metaheuristic CSO is applied with entropy fitness function to rank and select salient features for classification recognition.

Since, CSO is inspired by intelligent and social behavior of crows including memorization, thievery and food hiding strategy. Each crow will act as a candidate optimal feature subset, while its position corresponds to a probable solution within the feature space. The **Algorithm 1** operated in terms of memory-based searching, where crow memorized its best hiding locations possibly relate to optimal feature subset for this work. This act of crows is probabilistically protected them stolen from each other. For implementing this concept two impactful scenarios govern the position update: (i) a crow successfully monitors other's crow to its hidden location, (ii) one crow should allow to detect the hunt and arbitrarily changes its position. The parameters set for CSO based entropy driven feature optimization pipeline are given in **Figure 2**, whereas to implement the complete pipeline is given in **Algorithm 1**.

Algorithm 1 Proposed Feature Optimization Pipeline
Require: Input NST Binary Segmented Image
Generate: Multimodal Fused Feature Space (See **Figure 1**)
Ensure: Optimal and Relevant Feature Selection

Step 1: ***Initialization***

1. Initialize a population of P crows (flock size f).
2. Each crow represents a candidate feature subset with position

$$\mathbf{v}_i^{itr} = [v_{i,1}^{itr}, v_{i,2}^{itr}, \ldots, v_{i,dm}^{itr}]$$

   where $dm = N \times 3810$.
3. Initialize the memory $\mathbf{m}_i^{itr}$ of each crow with its initial position.
4. Set algorithm parameters: awareness probability ap, flight length fl, and maximum iterations.

Step 2: ***Fitness Evaluation***

5. For each crow, compute the entropy-based fitness using:

$$Entropy(\mathbf{v}_j^{itr}) = -\sum_{j=1}^{f} R_x(v_j^{itr}) \log_2(R_x(v_j^{itr}))$$

6. Higher entropy indicates a more informative and salient feature subset.

Step 3: ***Position Update***

7. For each crow i, randomly select another crow j to follow.
8. Generate random numbers $r_i, r_j \in [0, 1]$.

Case 1: Crow j is unaware of being followed

$$\mathbf{v}_i^{itr+1} = \mathbf{v}_i^{itr} + r_i \times fl \times (\mathbf{m}_j^{itr} - \mathbf{v}_i^{itr})$$

Case 2: Crow j is aware

$$\mathbf{v}_i^{itr+1} = \text{Randomly choose a new position}$$

Step 4: ***Memory Update***

9. Evaluate the fitness of the new position $\mathbf{v}_i^{itr+1}$.
10. If the new position yields higher entropy than the stored memory:
    - Update crow memory

$$\mathbf{m}_i^{itr+1} = \mathbf{v}_i^{itr+1}$$

    - Otherwise, retain the previous memory.

Step 5: ***Termination***

11. Repeat Steps 2–4 until the maximum number of iterations is reached.
12. Select the crow with the highest entropy-based fitness.
13. Output its memorized position as the **optimal salient feature subset**

The outcome of **Algorithm 1** is optimized feature subset that only contains non-redundant and relevant features. Subsequently, it provides to classifiers to improve classification accuracy, reliability, convergence and generalizability along with minimize computational complexity.

4. Results and Discussions

This section shows accuracy-based results of proposed optimization pipeline. The proposed technique is compared with state-of-the-art other metaheuristic methods including GA, PSO and ACO in similar conditions. The selected datasets SVT, KAIST and MSRA-TD 500 are extremely challenging for generating comparable accuracy. The proposed technique is programmed and tested in MATLAB 2018b by utilization GTX 1070 GPU with 6.1 compute capability.

4.1 Quantitative Results of Proposed Feature Optimization Technique

The current experiment has considerable relation with proposed framework. To avoid biasness and justify the eminence of the proposed framework it is compared with other benchmark naturally inspired optimization approaches. It is also evidently submitted and confirms from the review related work that use of proposed CSO based entropy driven technique is maiden attempt in scene text recognition.

The Tables 1-to-3 truthfully declares the supremacy of proposed technique when employed on all mainstream NST datasets and ensemble classifiers. It is clearly noticeable form the Tables 1-to-3 that CSO dominates in terms of accuracy levels yielding 97.6%, 94.6%, 95.6% on SVT, MSRA-TD500 and KAIST respectively. However, the other counterparts could not manage to achieve such high levels. Hence, it obviously confirms that CSO based entropy driven approach perform better in generating and selecting optimal features which as a result increase the generalizability, convergence and reliability of classification accuracy and performance.

Table No 1: (%) Accuracy based Results on SVT Dataset

Classifiers	GA	PSO	ACO	Proposed
L-SVM	**81.1**	**81.4**	**83.5**	**97.6**
C-SVM	80.2	85.7	82.4	95.6
Q-SVM	80.7	86.1	85.3	97.2
KNN	81.0	87.2	88.1	96.2
DT	79.4	84.3	83.8	97.1

Table No 2: (%) Accuracy based Results on MSRA-TD500 Dataset

Classifiers	GA	PSO	ACO	Proposed
L-SVM	**80.1**	**86.4**	**84.3**	**94.6**
C-SVM	79.2	86.1	84.6	92.6
Q-SVM	80.7	86.3	89.7	94.2
KNN	81.0	87.4	88.4	93.2
DT	78.5	84.1	88.8	93.1

Table No 3: (%) Accuracy based results on KAIST Dataset

Classifiers	GA	PSO	ACO	Proposed
L-SVM	**80.6**	**86.2**	**84.3**	**95.6**
C-SVM	78.7	80.4	81.6	94.6
Q-SVM	80.7	86.5	83.4	94.2
KNN	81.3	87.4	86.5	94.2
DT	78.9	84.9	87.9	95.1

3. Conclusions

The work proposed CSO based feature optimization and selection to identify and utilize salient features from fused feature space in novel contribution in improving classification convergence and generalization under sever scenic variabilities. The implication of entropy driven fitness function effectively shrinks and reduce feature redundancy while preserving discriminative information. As a result, improve classification accuracy and robustness is achieved. However, iterative working of the proposed framework opens up supplementary computational overhead when high dimensionality feature space is there. Moreover, the current work only focused on feature level optimization without considering classifier parameter tuning jointly. In future, the current work may be extended to explore jointly feature-classifier optimization approach with adaptive and hybrid CSO variants. It also further extended to multilingual and real-time scene text recognition tasks.

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