A First Approach to Refine Semantic Spaces in Zero-Shot Learning with a Genetic Algorithm

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Introduction

Abstract

Leveraging the capabilities that **Evolutionary Computation** has recently offered in **GPAIS**, we propose a tailored genetic algorithm **(GAZeLa)** to perform feature selection in the semantic space, removing irrelevant features that negatively affect generalisation capabilities in the **Zero-Shot Learning** paradigm.

Previous Works

No contribution treats the **Semantic Space** to enhance model performance in the literature, except for one work. Nevertheless, it presents many inconveniences as the expert must choose, after applying test data, the correct approximation. In this work, we compare the results obtained using that approach (SVC-T3/T4 & RF-T3/T4) with our proposal.

Zero-Shot Learning

Zero-Shot Learning is a paradigm that allows us to perform a task, in this context, image classification, at the test stage **without being previously trained for it** by **transferring knowledge** from seen classes to unseen classes via the **Semantic Space.**

Semantic Spaces

- It may be engineered-based or learned-based
- It may contain unnecessary information
- It may contain biases and errors

Experimental Framework

Datasets

- Animals with Attributes 2 (AWA2)
- Scene Understanding (SUN)
- Flowers with Attributes (FLO)
- Caltech-UCSD Birds-200-2011 (CUB)

Fitness Function

- Split the labeled data into pseudo-seen (PS) and pseudo-unseen (PU) subsets (disjoint)
- Semantic Autoencoder (SAE)
- Train the SAE on PS and use its accuracy on PU as the fitness measure, simulating real performance on unseen classes.

Methodology

GAZeLa

Selection Operator (SO)

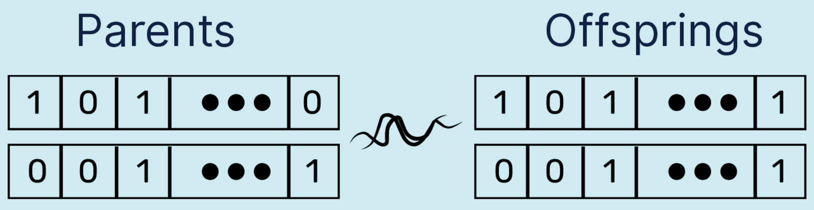
p_1 = Select randomly from the Top k individuals of $\mathcal{P}$

$$p_2 = \underset{c \in \mathcal{P}}{\text{argmax}} \left[\alpha \cdot d_{\mathcal{H}}(p1, c) + (1-\alpha) \cdot ||f(c)|| \right]$$

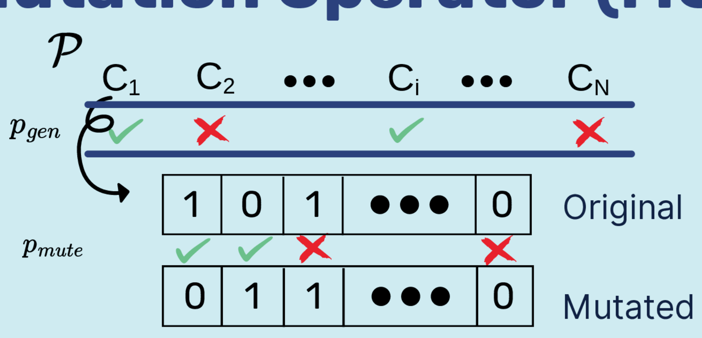
Trade-off, Hamming Distance, Fitness Function

Crossover Operator (CO)

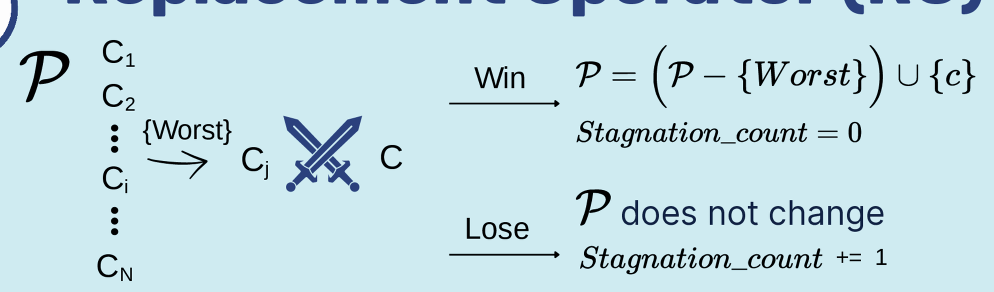
Binary Uniform Crossover Operator



Mutation Operator (MO)



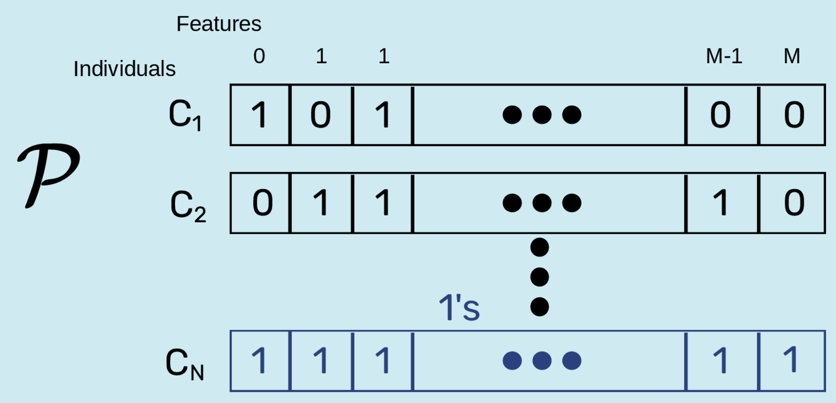
Replacement Operator (RO)



Input: Population size N, Generations limit G, Mutation probability p_{mute}, Gen mutation probability p_{gen}, catastrophic replacement rate c_{rate}.

```
Initialize random seed and population
while generations do not reach G do
    Select parents p1, p2
    Generate offspring c1, c2
    if p_mute then
        Mutate c1, c2 via MO according to p_gen
    end if
    Insert c1, c2 into population
    if stagnation in replacement detected then
        Apply catastrophic mutation according to c_rate
    else if stagnation in convergence detected then
        Apply catastrophic mutation according to c_rate
    end if
    Update best solution
end while
return best semantic space's configuration
```

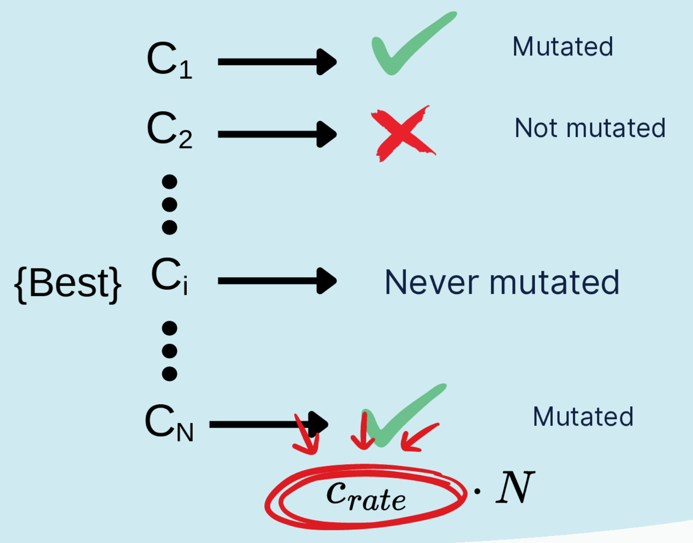
Init Population



Initialization uniformly across the number of features according to

$$g(i) = \lceil p_{min} * M \rceil + \left\lceil \frac{(1-p_{min})M}{(N-1)} i \right\rceil$$

Catastrophic Mutation Operator (CMO)

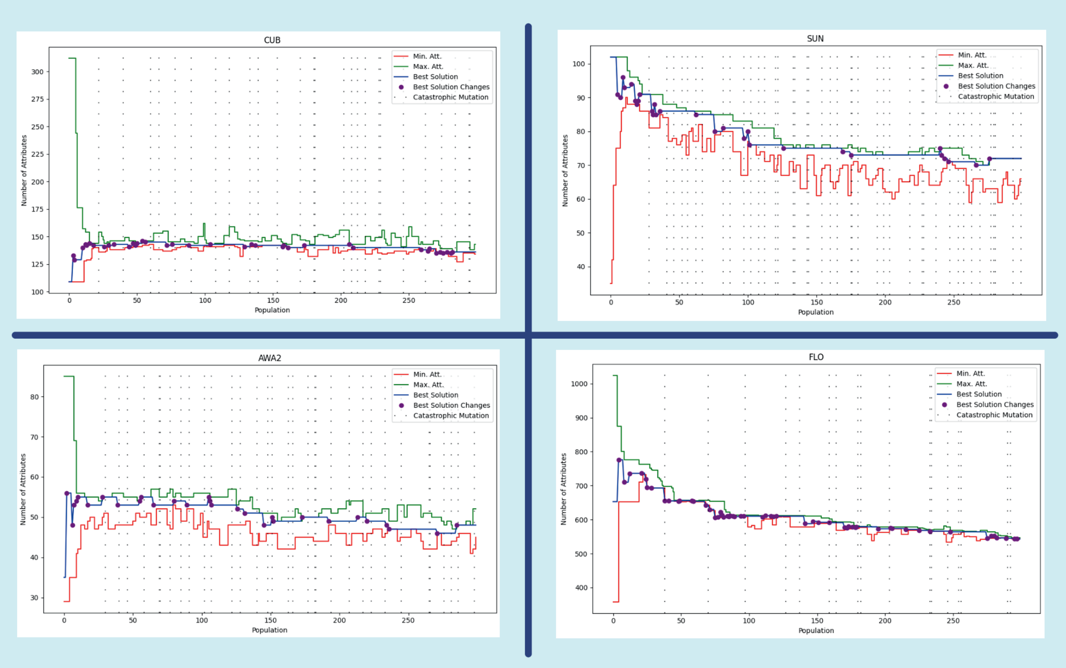


Results

Dataset	Baseline	RF-T3	RF-T4	SVC-T3	SVC-T4	GAZeLa
AWA2	40.364	42.525	42.639	42.260	42.158	**44.168**
SUN	38.819	38.681	38.681	39.681	39.236	**42.500**
CUB	33.468	34.446	35.356	34.580	34.783	**40.007**
FLO	34.892	34.026	32.814	36.450	35.152	**36.797**

Dataset	Atts	RF-T3	RF-T4	SVC-T3	SVC-T4	GAZeLa
AWA2	85	-11.76%	-24.71%	-5.88%	-8.24%	-16.47%
SUN	102	-0.98%	-3.92%	-1.96%	-1.96%	-30.39%
CUB	312	-17.95%	-37.82%	-9.29%	-16.35%	-56.41%
FLO	1024	-7.42%	-33.40%	-53.61%	-74.02%	-46.88%

Convergence



Conclusion

- GAZeLa significantly surpasses the other approach
- A considerable reduction of the semantic space is achieved
- Premature convergence

Future Works

- Refine GAZeLa by promoting a better exploration
- Integrate GAZeLa in the GZSL paradigm

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